MOUTH HYGIENE

A COURSE OF INSTRUCTION FOR DENTAL HYGIENISTS

A TEXT-BOOK CONTAINING THE FUNDAMENTALS FOR PROPHYLACTIC OPERATORS

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With 278 Illustrations and 7 Plates

LEA & FEBIGER

PHILADELPHIA AND NEW YORK

1916

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PREFACE.

DENTISTRY is in a position today where the problem of mouth hygiene must be solved in a practical manner. The medical profession now realizes that unsanitary mouths with diseased teeth are a very potent factor for ill health and systemic infection.

Although many of the leading investigators and writers of the dental profession have repeatedly called attention to the mouth as a cause for systemic disease, the cry has not been heard by the mother profession until a comparatively recent period. Now that we know that this gateway to the body must be kept clean, the teeth sound and the gum tissue maintained in a healthy condition, the question arises how such an enormous work as that which is before our profession can be successfully accomplished. Surely the dentists alone cannot cope with it.

Judging from the condition of the mouths of the children in our public schools, fully 90 per cent. of the population of this country has decayed teeth. If all the dentists in the United States devoted all of their time to reparative work alone, they could not take care of one-eighth of the people. But operative dentistry is expensive. It is beyond the means of the great working class who need sound teeth and good health. There must be some cheaper and better solution than merely to follow the endless chain of repair. We must get at the source of this universal disease and try to check it by educational and preventive means.

The source is the children in our public schools. We know that with extreme cleanliness, the elimination of improper foods and with surface treatments of the teeth at regular intervals, fully 90 per cent. of dental decay can be eliminated. If this knowledge and service is to be given to the children as well as to those adults who are patients in private practice, who is to give it? Apparently the only solution is the woman who is educated and trained as a dental hygienist.

This is woman's work and there is an immense field open for thousands of women in dental offices and public institutions. Such a course of education and instruction should also be annexed to the training of the medical nurse, as her services for mouth hygiene in the hospitals and sanitariums would soon prove to be invaluable. These questions have repeatedly been asked, "Where are we going to secure such women. educated and trained as dental hygienists? Where are they to secure such an education? What should constitute such a course for lectures and practical training? Are there text-books that they may study to comprehend and perfect themselves in this preventive work?"

The main object of this publication is to present a definite answer to these questions and introduce an educational course for dental hygienists that will prove to be something definite and tangible at the start.

In the fall of 1913 the gentlemen whose names appear as contributors to this work were approached and asked if they would aid in such a cause, if they would come to Bridgeport and deliver their lectures to a class of thirty-two women, the lectures to be taken in shorthand, sent to them for correction and condensation so that the pith of the subject might be published in a text-book for the education of women assistants in prophylaxis.

Without exception these gentlemen agreed to come. The lectures were held in the evenings on Mondays, Wednesdays and Fridays, and with the exception of a vacation at Christmas time, ran from November 17 until March 30.

The class assembled at 7.30 P.M. and a review of previous lectures was taken up by one of the quiz masters. At 8 P.M. the lecturer of the evening commenced, and lectured until 9.30 P.M. or thereabouts. Eleven written examinations were held and out of a class of thirty-two, all but six passed with an average above 70 per cent., and nine passed above 90 per cent.

It is our earnest desire that educational institutions, such as dental colleges, will take up this work and establish a course of education and training for women as dental hygienists. We believe that the title, dental nurse, is a misnomer, as these women are not to perform any service that resembles the work of the medical nurse. They are prophylactic operators and, although they have a knowledge of dental diseases, their service is limited by law to prophylactic work. When the value of a service such as theirs is fully appreciated by the dental and medical professions, there will be a great demand for these practical workers for mouth hygiene, not only in private offices but in the public schools. It is our hope that this educational course will help to speed the day.

A full description of the methods employed for the practical training will be found in the appendix.

Aside from our obligation to the lecturers, quiz masters, a loyal office force and a number of kind friends who are influential in the dental profession and whose aid proved so valuable, we are also grateful to the S. S. White Dental Manufacturing Company for their display of generosity in loaning us sixteen new Diamond chairs for our course in practical training.

A. C. F.

BRIDGEPORT, CONN., 1916.

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MOUTH HYGIENE.

CHAPTER I.

ANATOMY.

By RAYMOND C. OSBURN, Ph.D.

ANALYSIS OF THE ORGANISM.

Anatomy is the science which treats of the *structure* of *organisms* or living beings. The different parts of an organism, called *organs*, are each fitted for the performance of one or more kinds of work. Any particular kind of work, or special part of the vital process, is known as a *function*.

Organs are said to be specialized or differentiated for the performance of their various functions. Structural differentiation enables an organ to perform its particular duty more readily, hence we say that it is adapted to its function. Thus in the human body the liver, kidney, ear and eye have certain definite kinds of work to do, and so on throughout the long list of organs. This setting aside of special parts for particular uses, termed *biological division of labor*, has come about gradually during the course of evolution.

Anatomy is not only interesting in itself, but it is necessary to the study of physiology and the phenomena of life generally. One would not expect to understand how a watch keeps time until he knew the parts concerned, as the main spring, the hair spring, the balance wheel, etc., and the relationship which these parts bear to each other. So one need not expect to understand how the human body does its work without knowing the parts that enter into its formation and how these are related in the body complex. Furthermore, in this course of study, in preparation for work upon an important part of the body, anatomy has an intensely practical interest.

SYSTEM OF ORGANS.

One of the first things we observe when we examine the organs of any higher animal is that they are often related to each other in a definite way for the purpose of carrying on some work too complicated to be handled satisfactorily by a single organ. Such arrangements of organs are called *systems*. In the alimentary system, for example, the mouth, the pharynx, gullet, stomach, small intestine, and large intestine are all distinct organs having different functions to perform, but all operate in series to handle, digest and absorb the food. Similarly, in the circulatory system, the heart, arteries, capillaries, veins, and lymphatics all have different things to do, but all work together toward the one end of circulating the fluids of the body.

Classification of Systems:

Nutritional	Alimentary	Individual.
	Respiratory	
	Circulatory	
	Excretory	
Relational	Motor	
	Supporting	
	Nervous	
	Reproductive	Racial.

The *nutritional systems* are those which supply food and oxygen, circulate or distribute them, and collect wastes and eliminate them from the body; in other words they work in harmony toward the nutrition of the body. The *relational systems* relate or coördinate the various parts of the body with each other and the organism as a whole with the outside world. All of these are concerned primarily with the welfare of the individual, so may all be classed together as the *individual systems*. On the other hand, the *reproductive system* has to do with the propagation of the species and is therefore of *racial* importance. The various systems and their organs will be considered separately later.

STRUCTURE OF ORGANS; HISTOLOGY.

Anatomy does not stop with the analysis of the organism into organs but considers also the structure of the organs themselves. Here again we find both structural differentiation and division of labor, for these always go hand-in-hand, and each part of every organ is developed in its particular position and is structurally suited to its special duty.

The study of the organs and systems is commonly called *gross anatomy*. The finer parts of which the organs are made up must be studied with the aid of a microscope, and this field of work is therefore known as *microscopic anatomy* or *histology*.

Tissues.—The organs of the human body, in spite of their manifold duties, are made up of a very limited number of common building stuffs. These we call *tissues*.

An organ consists of several kinds of tissues intimately bound together. The hand, for example, though one organ, consists of the skin, muscles, bones, cartilages, nerves, blood, fat and fibrous connective tissues. The tongue consists of epithelial tissue on the outside, while within are several sets of muscles, the nerves, blood and connective tissues. And so in any organ various sorts of tissues are blended, according to the work for which it has been specialized.

Furthermore, the same tissue may be found in different organs. Thus, no organ is without nervous tissue for sensation and for coördinating and regulating the parts; muscular tissue is distributed in all the organs of the body, and connective tissues occur everywhere to bind the other parts together.

Classification of Tissues:

I. Epithelial.
II. Supporting.
III. Circulatory.
IV. Glandular.
V. Motor.
VI. Nervous.
VII. Reproductive.

These may be taken up in order for further discussion.

I. *Epithelial tissues* are those which cover surfaces on or within the body, such as the epidermis forming the outer skin; mucous membranes which line the alimentary tract, the lungs, the air passages, and the nasal cavities; and serous membranes (sometimes called endothelial) which line the closed cavities of the body, as the peritoneum of the general abdominal cavity, the pleuræ lining the space about the lungs, the lining of the heart and bloodvessels, etc.

II. *Supporting tissues* are of many kinds and serve variously to give form and rigidity, to connect organs and to bind other tissues together that they may be held in their proper place. *Bone* forms the general skeletal framework and is the firmest of all the tissues. *Cartilage,* or gristle, serves to support parts that need more or less flexibility, such as the external ear and the tip of the nose, as well as to connect the ribs with the breast-bone or sternum, and it is usually found also between the bones at the joints where it prevents shock. *Tendons* are found chiefly as the cords which connect the muscles with the bones to which they are attached. *Ligaments* bind the bones together at the joints and hold certain other organs in place. *White fibrous tissue,* in the form of minute crinkly fibers, is distributed everywhere among the other tissues (except in epithelia which it underlies) and forms the common binding substance which holds other tissues in place. *Yellow elastic tissue* is made up of delicate, straight, branched fibers that are like so many little rubber bands. It serves to pull back into place any tissue that has been temporarily distorted.

III. The *circulatory tissues* consist of the blood and lymph cells, together with the fluids in which they are carried.

IV. *Glandular tissues* are those which have the power of picking up minute quantities of substances from the blood and concentrating them, or of elaborating substances into the forms in which they are again given out in secretion and excretion.

V. *Motor tissues* consist of muscle cells of three different kinds; the unstriped or involuntary, such as those in the wall of the intestine; the cardiac, which form the muscular walls of the heart; and the striped or so-called voluntary muscle cells, which form the great mass of the body wall and limb muscles.

VI. *Nervous tissues* are made up of the nerve cells with their fibers and the end-organs of the special senses.

The *brain* and *spinal cord* are merely aggregations of nerve cells and fibers bound together by connective tissue.

VII. *Reproductive tissues* are differentiated in the two sexes. In the female they are the *ovarian tissues* which give rise to the ova or egg cells and in the male they are the *spermatic tissues* which give rise to the male cells or spermatozoa.

Tissues can perform only the particular kinds of work for which they are adapted, and each cell of any tissue performs the same function as all the other cells of that tissue. This is true no matter in what part of the body they may be located. Thus, muscle cells contract, though found in the hand, heart, eye, or stomach; nervous tissues are capable of stimulation and conduct impulses wherever they may be, etc.

A *tissue* may be best *defined* as consisting of similar cells all of which do the same kind of work.

The Cell.—Cells are the fundamental structures of the organism. They are the physical units, out of which all the tissues, therefore all the organs, and the organism itself, are constructed. Cells differ greatly among themselves in size, form, internal structure and in function.

They are *classified according to the tissues* in which they occur. Thus in epithelial tissue we find epithelial cells, bony tissue contains bone cells, glandular tissue contains gland cells, and so on through the list.

Structure of the Cell (Fig. 1).—The all-important substance in the cell is that to which we apply the name *protoplasm*. It was originally applied to the living matter of minute one-celled organisms, and meant, therefore, the simplest living substance. But later chemical and microscopic studies have shown that this substance has the same general properties as the living matter of all cells of all organisms, both plant and animal.

Protoplasm, in all probability, is a mixture of substances, chemically speaking, but the one thing that distinguishes it at once from any other material is the fact that it is alive. All the functions of the body, no matter what they are, originate directly in the protoplasm. It should be evident that it varies somewhat in the different cells, since these are capable of doing different kinds of work. However, in all cases the work is performed by living matter and there is no living substance but protoplasm.

Under the microscope the protoplasm appears as a rather thickish, nearly clear fluid, which is usually slightly granular, but may appear quite homogeneous when alive.

The protoplasm in a cell is divided into two portions. The larger part forms the general cell fluid, known as the *cytoplasm.* Within this, usually near the center of the cell, is the *nucleus.* This consists of a denser fluid which does not mix with the cytoplasm. Occasionally more than one nucleus is present. Both the cytoplasm and the nucleus are alive, and both take part in the activities of the cell.

Usually there is also present a limiting membrane about the protoplasm, forming the *cell wall* or *cell membrane.* This structure is not living and therefore is not protoplasm, but it is formed by the protoplasm as a secretion.

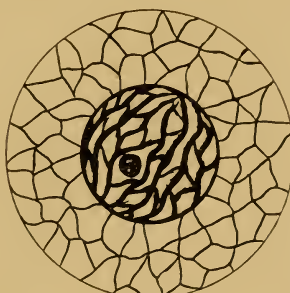


FIG. 1.—Diagram of a cell. (F. H. Gerrish.)

Intercellular Substances.—In addition to the living matter of the body, forming the cells, there is present a great deal of very essential non-living matter which is known as *intercellular substance,* because it is found between the cells. This substance varies in extent and character according to the tissue of which it forms a part. One would not expect to find the same kind of intercellular substance between the cells of the brain as in muscle, nor the same in bone as in cartilage, and so on. It is secreted by the cells which are embedded in it. It may be very scanty, as in the epidermis, or abundant, as in the connective tissues. If we examine cartilage (Fig. 2) we find that the cells are imbedded in a mass of translucent, rubbery material, which is present in such quantity that the cells are often widely separated. It is this substance which gives cartilage or gristle its peculiar toughness and elasticity. Tendons are composed of parallel fibers between which the cells are imbedded. These tough, inelastic fibers, which form the larger part of the tendon, give it its special character as the connecting structure between muscle and bone. In the bones and teeth the intercellular substance is impregnated with lime salts to give great hardness and rigidity. The supporting and connecting tissues in general contain great quantities of intercellular matter.

To SUMMARIZE: *cells,* consisting of protoplasm, together with the intercellular substance, make up the tissues. *Tissues* are intimately blended to form organs. *Organs* may function alone or in connection with others in *systems*. The whole complex of organs and systems makes up the *organism* or living body.

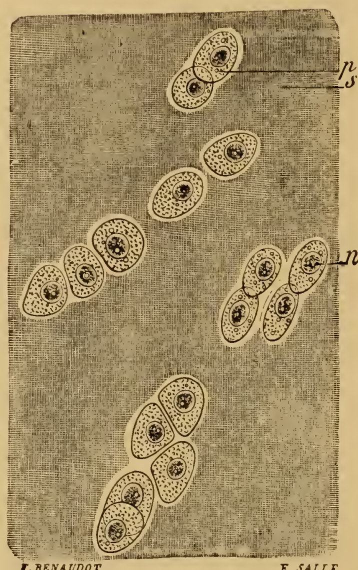


Fig. 2.—Articular hyaline cartilage from the femur of an ox: *s*, intercellular substance; *p*, protoplasmic cell; *n*, nucleus. (Ranvier.)

THE NUTRITIVE SYSTEMS.

Organs have already been defined as parts of the body which perform different kinds of work, and systems as series or groups of organs which work together toward some greater end than can be attained by a single organ. It is axiomatic, of course, that no organ or system is entirely independent of the others. This conception is at least as old as Æsop's fable of "The Belly and the Members." However, for the purpose of analysis they may be considered separately.

The alimentary, respiratory, circulatory, and excretory systems have already been mentioned as forming the nutritional group. All of these systems are concerned with supplying nutritive substances to the body or its various parts, or with the removal of wastes that have accumulated in the process of nutrition and work.

The real *chain of events in nutrition* is as follows:

1. Alimentation, the mechanical handling of the food.
2. Digestion, the chemical breaking up of the food.
3. Absorption of food and water by the alimentary system.
4. Absorption of oxygen by the respiratory system.
5. Circulation, to pass these substances to the cells where they are used.

6. Metabolism.
    (*a*) Anabolism, the building up or constructing phase, by which foods are converted into protoplasm or into something out of which the protoplasm can obtain energy.
    (*b*) Katabolism, the breaking-down process by which energy is released and wastes are formed.

7. Circulation again in order to collect the wastes formed in the cells and deliver them to the places where they can be eliminated.

8. Excretion in its various phases, involving especially the kidneys, lungs and skin.

All of the above processes, except those of metabolism which take place in all the cells of the body, are carried on by the four systems mentioned above.

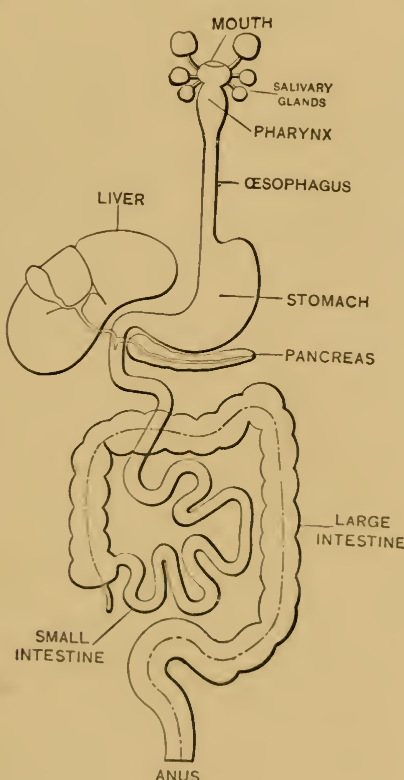


Fig. 3.—Diagram of the alimentary tube and its appendages. (Testut.)

THE ALIMENTARY SYSTEM (Fig. 3).

In this system are included all those organs which make up the food tube through the body, beginning with the mouth and ending with the anus, together with a number of appended organs. We may list these as follows:

1. Mouth.
2. Pharynx.
3. Esophagus or gullet.
4. Stomach.
5. Small intestine.
6. Large intestine or colon.
7. Anus.

These parts make up the alimentary tube, but, to complete the system, there must be added the following glands:

8. Salivary glands.
9. Pancreas.
10. Liver.

The alimentary tube is much longer than the body through which it runs, being in all about twenty-eight feet in length. Most of this length is found in the small and large intestines which are folded back and forth in the abdominal cavity to accommodate them to the space.

Organs of the Alimentary System.—1. **The Mouth.**—The mouth will be considered in detail in the chapter on Special Anatomy.

2. **The Pharynx.**—The pharynx is a musculomembranous passage, somewhat conical in form, about five inches in length, and suspended from the base of the skull just in front of the spinal column. Above, it communicates with the nose and mouth through their posterior openings. At its lower end and in front is the opening into the larynx, closed during the act of swallowing by the epiglottis. The pharynx is continued below into the esophagus.

On the upper portion of the lateral walls of the pharynx are seen the openings into the Eustachian tubes. Between these, on the posterior wall, is a mass of lymphoid tissue known as the pharyngeal tonsil. When this becomes hypertrophied, as it often does in children, it gives rise to the condition known as *adenoids*.

3. **Esophagus.**—This is a nearly straight tube, about nine inches in length, which extends from the pharynx to the stomach, behind the windpipe or trachea, piercing the diaphragm. As in other parts of the intestinal tract, its collapsible wall closes the passage except when food or water is passing through it. Its walls are provided with muscles to further the process of swallowing.

4. **Stomach** (Fig. 4).—This is the most expanded portion of the tube and serves as a crop or receptacle for food, in addition to which it assists in the digestion of the protein foods. It lies obliquely across the left side of the body just below the diaphragm. Its larger end, known as the *fundus*, is connected with the esophagus, and a sphincter or circular muscle, the *cardiac valve*, guards the aperture against the return of food into the esophagus. The smaller end, toward the right, is known as the *pylorus* and this communicates with the duodenum through an opening guarded by another sphincter called the *pyloric*

valve. The average capacity of the stomach is about a quart. It is lined with mucous membrane in which many small tubular glands, the *gastric glands,* are imbedded. It has three muscular coats, one more than the intestine, namely the longitudinal, the circular and the oblique,

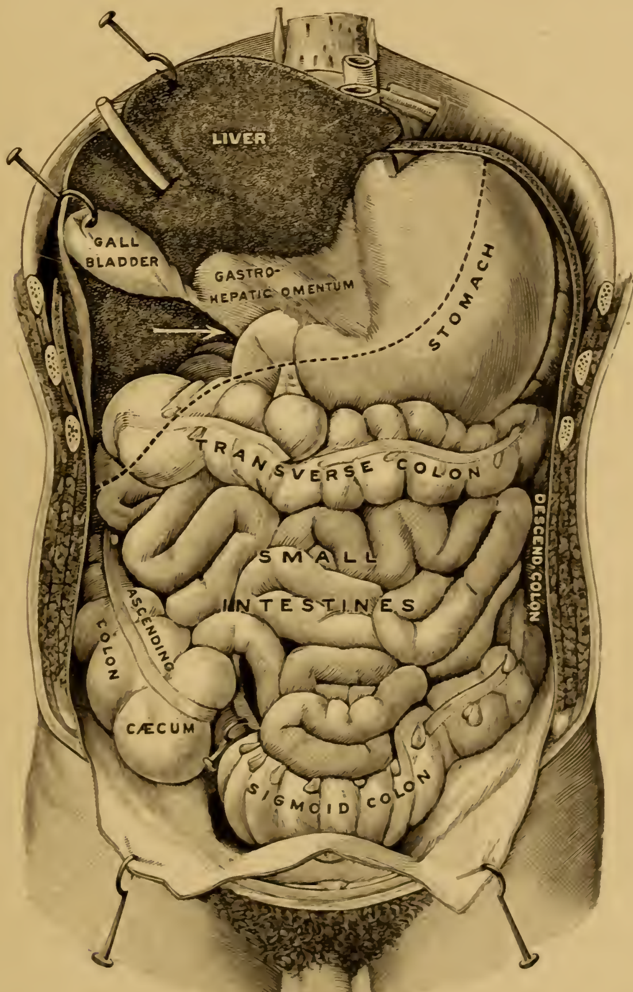


FIG. 4.—The stomach and intestines, front view, the great omentum having been removed, and the liver turned up and to the right. The dotted line shows the normal position of the anterior border of the liver. The dart points to the foramen of Winslow. (Testut.)

and is covered on the outside by the smooth serous layer of the *peritoneum* which prevents friction.

5. **Small Intestine** (Fig. 4).—This tube is about twenty feet long and varies in diameter from nearly two inches at its upper end to about an

inch at its lower end. It is composed of three parts, the *duodenum,* about eight inches long, the *jejunum,* about seven and a half feet long, and the *ileum.* These parts are not sharply marked off from each other and are not separated by valves. The mucous membrane of the intestine, like that of the stomach, is provided with tubular glands, the intestinal glands, and in addition its free surface is thickly studded with minute finger-like processes, the *villi,* which serve to absorb digested food. The muscular coats are the longitudinal and circular, and the outside is covered by the peritoneum except for a portion of the duodenum.

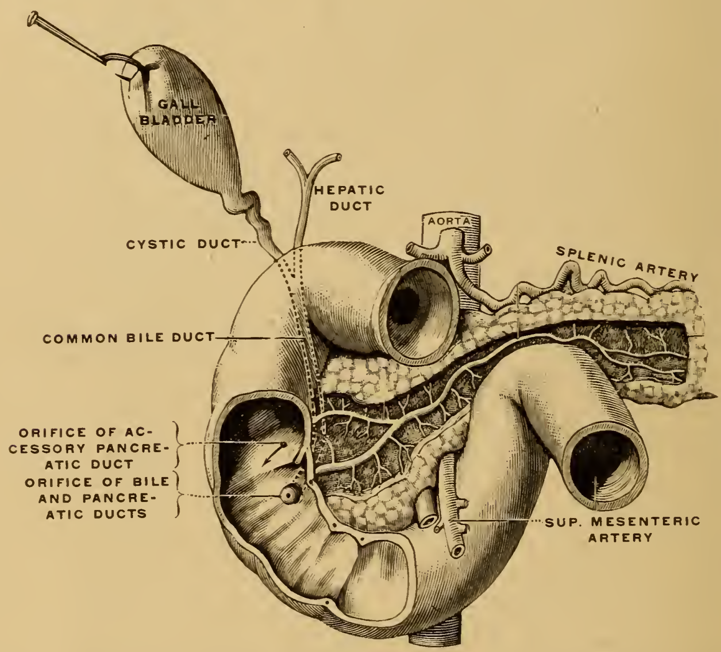


Fig. 5.—Ducts of the pancreas. Part of the front wall of the duodenum is cut away. (Testut.)

6. **Large Intestine** (Fig. 4).—The passage from the small to the large intestine is guarded by another sphincter muscle, the *ileocecal valve.* The large intestine is about five feet in length and two and a half to one and a half inches in diameter. At its upper end it extends past the junction with the ileum about two and a half inches to form a blind pouch, the *cecum.* The *vermiform appendix* is an extension of the cecum. This organ is about two inches in length and has the diameter of a lead-pencil. The colon proper begins at the ileum and first extends upward on the right side as the *ascending colon,* then across the abdominal cavity as the *transverse colon,* then downward on the left side as the *descending colon,* then toward the middle of the

body as the *sigmoid flexure*. The last portion, six or eight inches in length, forms the *rectum*. The mucous lining has no villi, but otherwise the coats are similar to those of the small intestine. The walls of the cecum and colon have a peculiar puckered appearance, due to the fact that the longitudinal muscles are arranged in three bands which are shorter than the rest of the wall.

7. **Anus.**—The lower opening of the intestine is lined with ectoderm and is guarded by two sets of muscles, the *internal* and *external sphincters*.

8. **Salivary Glands.**—Described in the chapter on Special Anatomy.

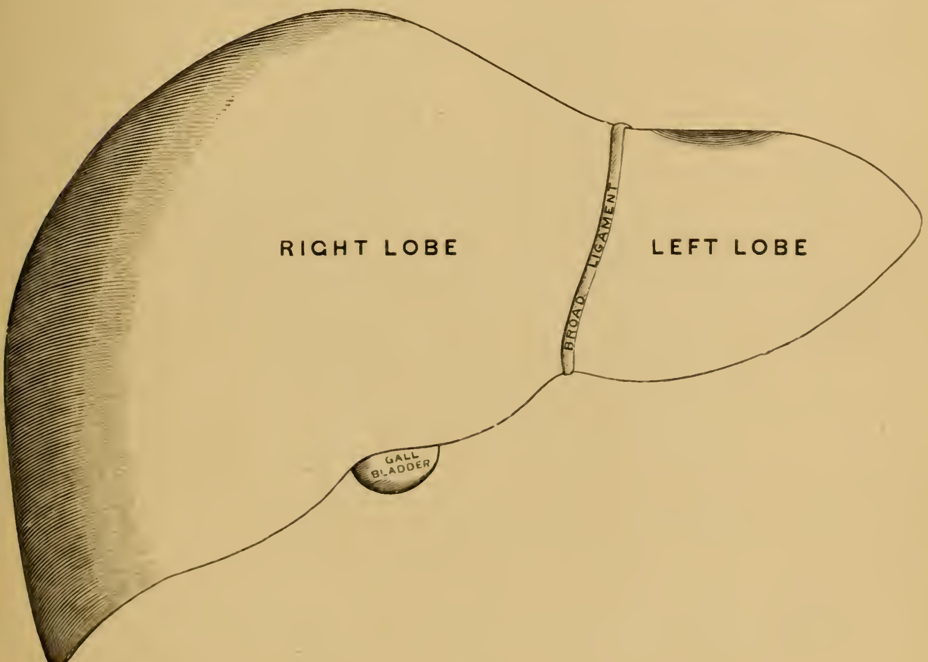


FIG. 6.—The liver, front view. (Drawn from the His cast. Gerrish.)

9. **The Pancreas** (Fig. 5).—The pancreas is a gland of irregular form, about six inches long, two inches wide, and one-half inch thick, which lies transversely behind and below the stomach. In weight it varies from two to three ounces. Its right end lies in the curve of the duodenum and its *duct* enters the duodenum along with that of the liver, two or three inches below the pyloric valve. It is the *most important digestive gland* of the body, since its secretion, the pancreatic juice, acts on all kinds of foods. The pancreas also contains numerous ductless glands (glands of internal secretion) about one twenty-fifth of an inch in diameter, the *islands* of *Langerhans*, which secrete important fluids into the blood.

10. **The Liver** (Fig. 6).—This organ weighs between fifty and sixty ounces and is therefore much the largest gland of the body. It lies close up against the diaphragm on the right side and middle of the abdominal cavity, and covers the small end of the stomach, the upper part of the ascending colon and the right kidney. It is very irregular

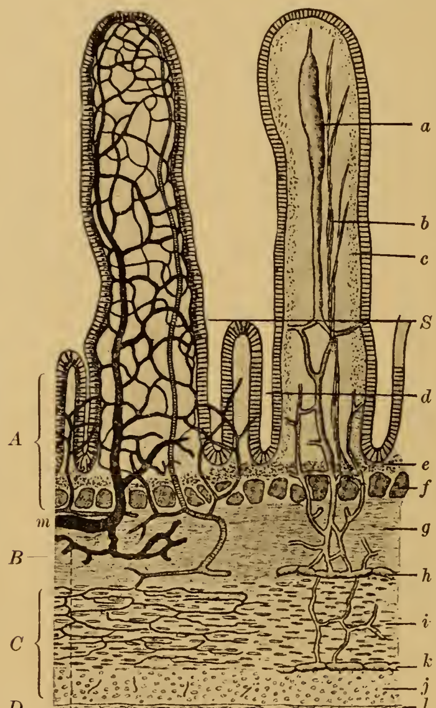


Fig. 7.—Diagram presenting the structure of the human small intestine. (Böhm, Davidoff, and Mall; slightly modified.) Two villi are represented. In the one on the left the bloodvessels are shown; in the one on the right, the lymphatics. The line *S* indicates the surface of the mucous membrane between the villi. *a*, central lacteal vessel; *b*, smooth muscular fibers extending into the villus from the muscularis mucosæ; *c*, lymphadenoid tissue beneath the epithelial covering of the villus; *d*, crypt of Lieberkühn; *e*, tunica propria of lymphadenoid tissue, and continuous with that of the villus; *f*, muscularis mucosæ, forming the deepest portion of the mucous membrane; *g*, submucosa containing the larger bloodvessels and the lymphatic plexus, *h; i*, encircling layer of the muscular coat; *j*, longitudinal layer; *k*, lymphatic plexus within the muscular coat; *l*, serous coat; *m*, vein. The crypts are lined, and the villi covered, with columnar epithelium. (Dunham.)

in form and consists of *five lobes*. It is held in place by *five ligaments*. The substance of the liver consists of the glandular cells arranged in lobules a little larger than the head of a pin. The *hepatic artery* carries pure blood to *nourish* the liver, and the *portal vein* carries a large supply of blood to it from the intestinal tract to be *worked over* by the liver before it returns to the general circulation. The *hepatic* *vein* returns the blood from both sources to the heart. The *bile ducts* arise among the liver cells and join to form the *hepatic duct.* This unites with the *cystic duct* of the *gall-bladder* to form the *common bile duct* which enters the intestine along with the pancreatic duct. The *gall-bladder* is a sac lying in a depression on the under side of the right lobe of the liver. It serves as a reservoir for the bile secreted between periods of digestion.

Histology of the Intestinal Tract.—The tissues which enter into the formation of the intestinal tube are arranged in the form of layers or coats, and, with slight differences, are similar throughout. The inner coat, next to the cavity, consists of *mucous membrane* (Fig. 7, *A*) made up of a single layer of cells backed up by loose connective tissue in which small tubular glands are imbedded. In the stomach the mucous

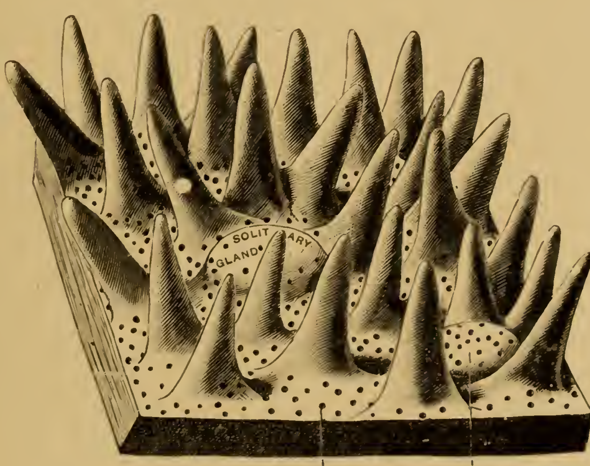


FIG. 8.—Free surface of the mucous membrane of the small intestine, showing villi, solitary glands, and openings of the intestinal glands. Semidiagrammatic. (Testut.)

membrane is not smooth, as it is in the mouth and gullet, but is thrown into irregular folds which are less pronounced as the stomach becomes filled. In the small intestine, in addition to *circular folds*, there are the small finger-like processes already described as the *villi* (Fig. 8). In the large intestine both the circular folds and the villi are lacking.

Outside of the mucous layer is the *submucous coat* (Fig. 7, *B*) consisting of loose connective tissues in which are distributed bloodvessels, lymphatics, and the nerves of the intestinal (Meissner's) plexus. *Lymph glands* (Peyer's patches and solitary nodules) are imbedded in this layer.

Next are found the *muscular coats* (Fig. 7, *C*), the *inner circular* and the *outer longitudinal*, with the nerves of the plexus myentericus between. In the stomach a third muscular coat with oblique fibers occurs inside of the circular coat. These muscles are responsible for the movements of the intestinal tube in handling the food. At various places along the tube the circular muscles are increased in size to form the *sphincter muscles* already mentioned which govern the passage of food from one part to another.

The outside layer of the tube is the *peritoneum* (Fig. 7, *D*), a layer of serous membrane which, by its smooth secretions, prevents friction when the various parts come in contact.

The intestine and stomach are held in place by a thin membrane of connective tissue (the mesentery), which is attached along the mid-line of the back wall and this tissue, as well as the inner wall of the body in the abdominal region, is covered by the peritoneum. A broad fold, the *great omentum*, also covered with peritoneum, extends downward between the intestines and the front wall of the body for further prevention of friction.

THE RESPIRATORY SYSTEM.

The two chief functions of the respiratory system are to supply oxygen to the body and to remove carbon dioxide which accumulates in the body as the result of oxidation or combustion within the cells. All the cells of the body are concerned in the use of oxygen and consequently in the formation of carbon dioxide, and the fluids of the body, blood and lymph, are concerned in the distribution of oxygen and in collecting the carbon dioxide preparatory to elimination. The respiratory system is thus left with only the work of delivering oxygen to the blood and the removal of carbon dioxide. The *primary apparatus* for this purpose consists of the moist membrane lining the air sacs of the lungs, but *accessory structures* are necessary for carrying the air to and from the absorptive area of the lungs. These are as follows:

1. External nares.
2. Nasal passages.
3. Internal nares.
4. Pharynx.
5. Glottis.
6. Larynx.
7. Trachea.
8. Bronchi and bronchioles.
9. Air sacs or alveoli.

In breathing the air enters these passages in the order given and passes out in the reverse order. The nares, nasal passages and pharynx will be discussed elsewhere. The *glottis* is the opening from the pharynx into the larynx. This opening, in the mammals, is provided with a hinged cartilaginous lid or flap, the *epiglottis* (Fig. 9), which closes the opening in the act of swallowing, thus preventing the entrance of food or water to the air passages. The *larynx* (Fig. 10), or voice box, is an expansion of the passage and consists of two special cartilages, the cricoid and arytenoid, by which the vocal cords can be regulated in the production of the voice. These cords are situated at the middle of the larynx in such a manner that they ordinarily permit the free

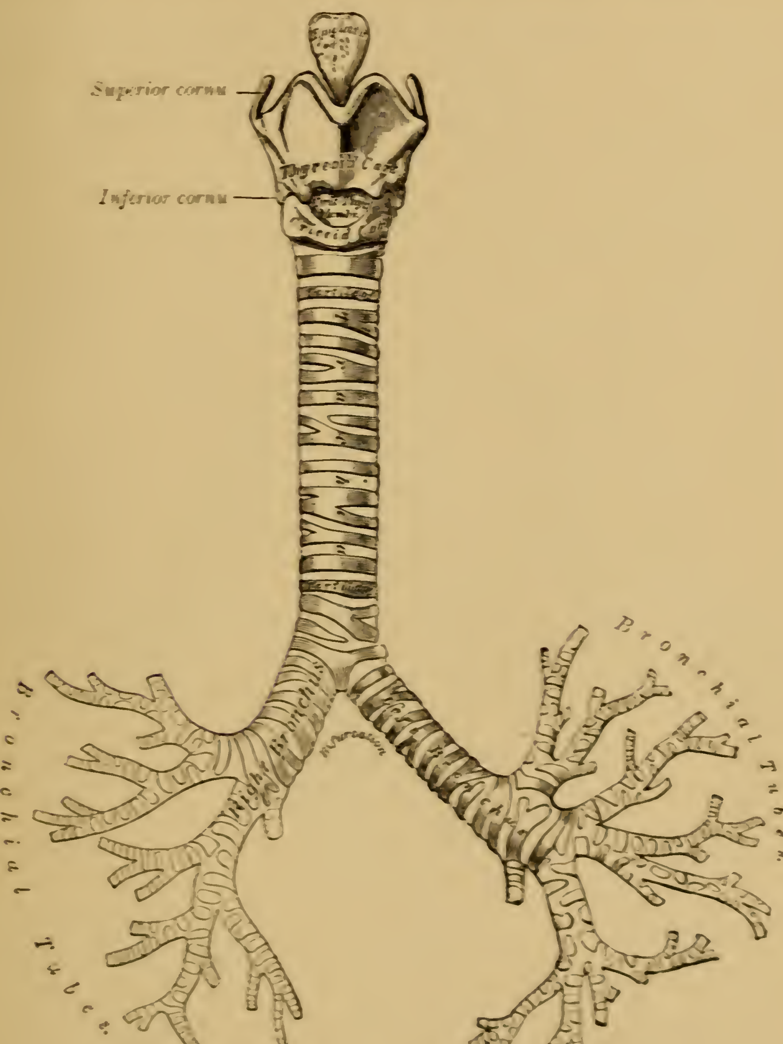


FIG. 9.—Front view of cartilages of larynx, trachea and bronchi. (Gray.)

passage of the air in breathing, but when stretched by the action of the laryngeal muscles upon the cartilages they approach each other and more nearly close the opening, when they are thrown into vibrations by the passage of the air.

The *trachea* (Fig. 9), or windpipe, is a tube from four to five inches long and about three-quarters of an inch in diameter, which extends downward into the thorax or chest between the lungs, where it divides into the right and left *bronchi*. Its walls consist of fibrous connective tissue and muscles, in which is imbedded a series of incomplete cartilaginous rings. These partial rings, with their opening behind and next to the esophagus, serve to keep the passage open for the free entrance of the air. The trachea, like the other air passages, is lined with mucous membrane and this membrane is provided with *cilia* or vibratile threads of protoplasm which constantly beat in an upward direction to sweep out any impurities brought by the respiratory current. The *right* and *left bronchi* enter their respective lungs and break up into large numbers of *bronchioles* or bronchial tubes, which have much the same structure as the trachea, but become thinner-walled as they become smaller and approach the air sacs.

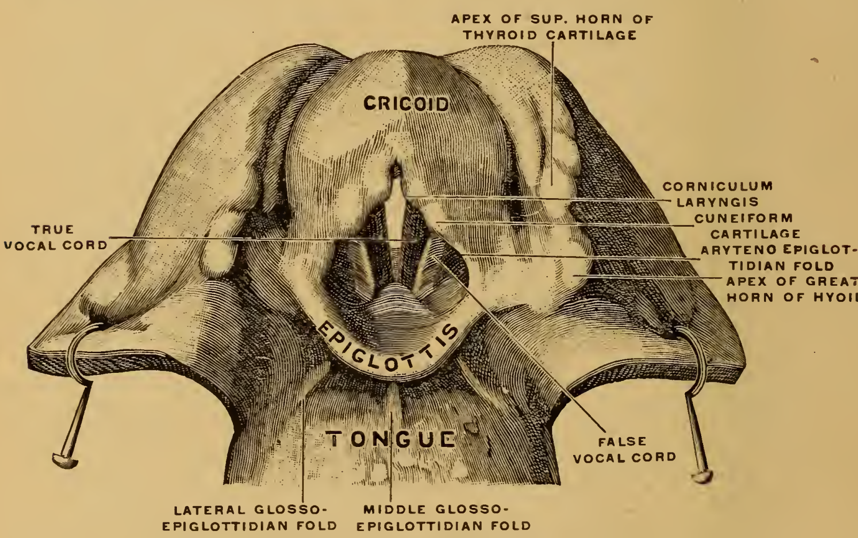


Fig. 10.—Larynx, viewed from above. (Testut.)

The Lungs (Plate I) are essentially composed of the *air sacs* or *alveoli*, which are present in such enormous numbers that their combined surface is equal to about eight hundred times the surface of the body. Thus it is not difficult to understand why they are such efficient organs for the exchange of gases. Each alveolus is lined with a thin layer of epithelial cells of the mucous membrane. The blood, in the pulmonary capillaries, is richly supplied to the alveoli, so that in making the exchange the gases have only to pass through the thin walls of the capillaries and the mucous membrane. The lungs occupy nearly all the space in the thoracic or chest cavity, except that occupied by the heart. The *right lung* is slightly larger than the left and

PLATE I

Diagram of a Lobule of the Lung.

A bronchiole is seen dividing into two branches, one of which runs upward and ends in the lobule. In the lobule are four groups of infundibula. At the left are two infundibula, the alveoli of which present their outer surfaces. Next are three infundibula in vertical section, the alveoli of each opening into the common passageway. Upon the ultimate bronchiole of this group are alveoli. In the next group the first infundibulum shows a pulmonary arteriole surrounding the opening of each alveolus, and the second gives the same with the addition of the close capillary network in the wall of each alveolus. The same arrangement of vessels is seen in the alveolus upon the bronchiole of this group. Around the fourth group is a deep deposit of pigment, such as occurs in old age, and in the lungs of those who inhale coal-dust and the like. On the bronchiole lies a branch of the pulmonary artery (blue), bringing blood to the infundibula for aëration. It also supplies nourishing blood to the tubes and other structures within the lobule. Beginning between the infundibula are the radicles of the pulmonary vein (red), a root of which lies upon the bronchiole. The bronchial artery is shown as a small vessel bringing nutrient blood to the bronchiole (outside of the lobule), the artery and vein, and all of the structures between and around the lobule. No attempt is made to show the sustentacular tissue which occupies the spaces within and around the lobule. (Gerrish.)

is composed of three lobes, upper, middle, and lower, while the *left* lung has only upper and lower lobes. The outer surface of the lungs and the inner surface of the chest wall are covered by the *pleura*, a smooth serous membrane which effectually prevents friction during the respiratory movements.

The Chest Wall.—In order to bring the air into the lungs it is necessary that the chest cavity be enlarged. This is done rhythmically by means of muscles. The *diaphragm*, which has already been mentioned as a partition separating the abdominal from the chest cavity, is a broad, thin sheet of muscle closing off the lower part of the chest and at rest is curved upward, somewhat like an inverted bowl. When in action the fibers of this muscle contract so as to make the diaphragm nearly flat, thus increasing the space above it. Also the *external intercostal muscles*, running from rib to rib, raise the ribs and so increase the diameter of the chest. The thoracic cavity is thus enlarged in a vertical direction by lowering the diaphragm and in a transverse direction by the action of the intercostal muscles. As the air passages are normally open the outside air rushes in to fill the partial vacuum created by enlarging the chest cavity. No special apparatus is ordinarily required for the expulsion of the air, for the abdominal wall has been pushed outward by the action of the diaphragm and the chest wall has been stretched by the action of the intercostal muscles, and when the muscular force is released the collapse of the abdominal and chest walls forces out the air from the lung. In rapid or forced breathing, however, the *internal intercostal muscles* forcibly contract the chest wall to hasten the process. In forced inspiration other muscles than those mentioned, attached to the upper part of the chest, may be brought into action.

THE CIRCULATORY SYSTEM.

This system consists of a pumping organ, the heart, and a set of conducting tubes, the arteries, capillaries, veins, and lymphatics, through which the fluids of the body are distributed to carry oxygen and foods to the various tissues and to collect the wastes and deliver them to the excretory organs.

The Heart.—The heart is a double muscular organ with four chambers, *two auricles* and *two ventricles*, which is lodged in a serous sac, the *pericardium*, in the lower part of the chest cavity nearly in the midline. (See Plate II.) We are accustomed to think of the heart as lying on the left side because its beat is felt most strongly there. The apex of the heart is tipped toward the left and also projects forward so that it comes nearest to the surface just at the left of the breast-bone below the fifth rib. Though the right and left sides of the heart really function separately, they are bound together in such a manner that they act simultaneously. The *right auricle* receives the blood from the system and pumps it into the *right ventricle* which in turn pumps it to the lungs (pulmonary circulation). The *left auricle* receives the blood from the lungs and delivers it to the *left ventricle* which sends it out to all parts of the body (systemic circulation). Because of the much greater work they have to do the ventricles are much thicker walled than the auricles, and for the same reason the wall of the left ventricle is much thicker than that of the right, since it pumps the blood much farther.

The *muscle cells* of the heart are of a special kind (cardiac muscle). They are short, block-like, and often branched, with a single nucleus at the center, with faint cross striations and without cell walls.

Between the auricles and the ventricles are the *auriculoventricular valves,* known on the right side as the *tricuspid* and on the left as the *mitral* (Plate III). These are soft flaps of connective tissue which are readily pushed out of the way when the blood is forced into the ventricles, but which close the openings into the auricles when the ventricles contract. They are held in place when closed by fibrous cords (*chordæ tendonæ*) which are provided with muscles at their bases (*papillary muscles*) so that they are held in the proper position as the ventricles contract. The *semilunar valves* similarly prevent the blood from returning from the arteries to the ventricles. These valves are located at the junction of the arteries with the heart. (See Plate II.)

The lining of the heart consists of a delicate layer of flattened cells, which is also continued as the inner coat of the bloodvessels.

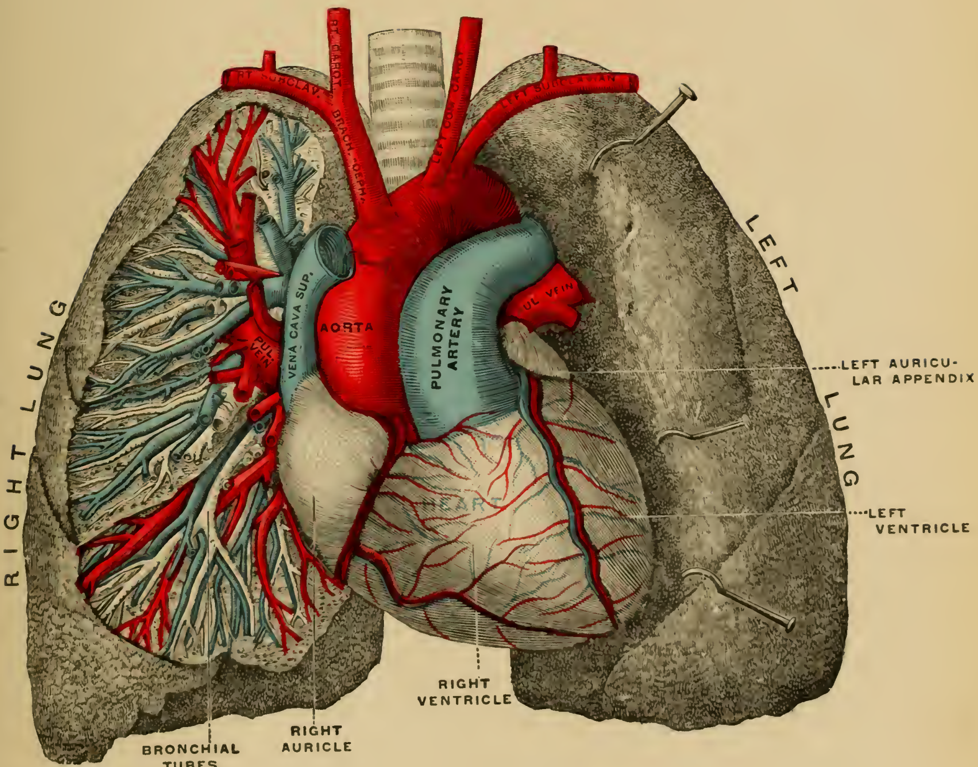
The *pericardium,* which encloses the heart, consists of a tough coat of connective tissue lined by serous membrane. It is in the form of a closed, double-walled sac, which is so arranged that the serous coat covering the heart comes into contact only with the serous lining of the pericardium, thus preventing friction.

The Bloodvessels (Plate IV).—The *arteries* are the vessels which carry the blood away from the heart. Their walls are thick and strong to withstand the pressure with which the blood is forced into them. At the same time they must be elastic enough to adapt themselves to the variations in pressure at different times. They are made up of white fibrous and yellow elastic connective tissues, with a layer of muscle tissue for regulating the size of the vessel. Sometimes, especially in old age, the walls become partially calcified, causing the condition known as arteriosclerosis. The arteries leave the heart as single vessels, the *pulmonary artery* from the right ventricle, the *aorta* from the left.

The *pulmonary,* going to the lungs, divides about two inches from the heart into right and left branches to enter the corresponding lungs.

The *aorta,* emerging from the left ventricle, supplies aerated blood to the whole body. The first branches are the *coronary,* which return at once to supply the tissues of the heart itself. The aorta curves backward above the heart forming the *arch* and is continued down the posterior portion of the thoracic and abdominal cavities as the

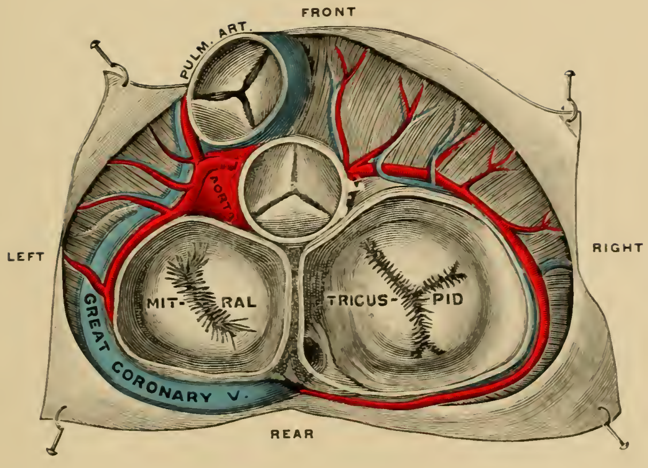
PLATE II



The Pulmonary Artery and Aorta.

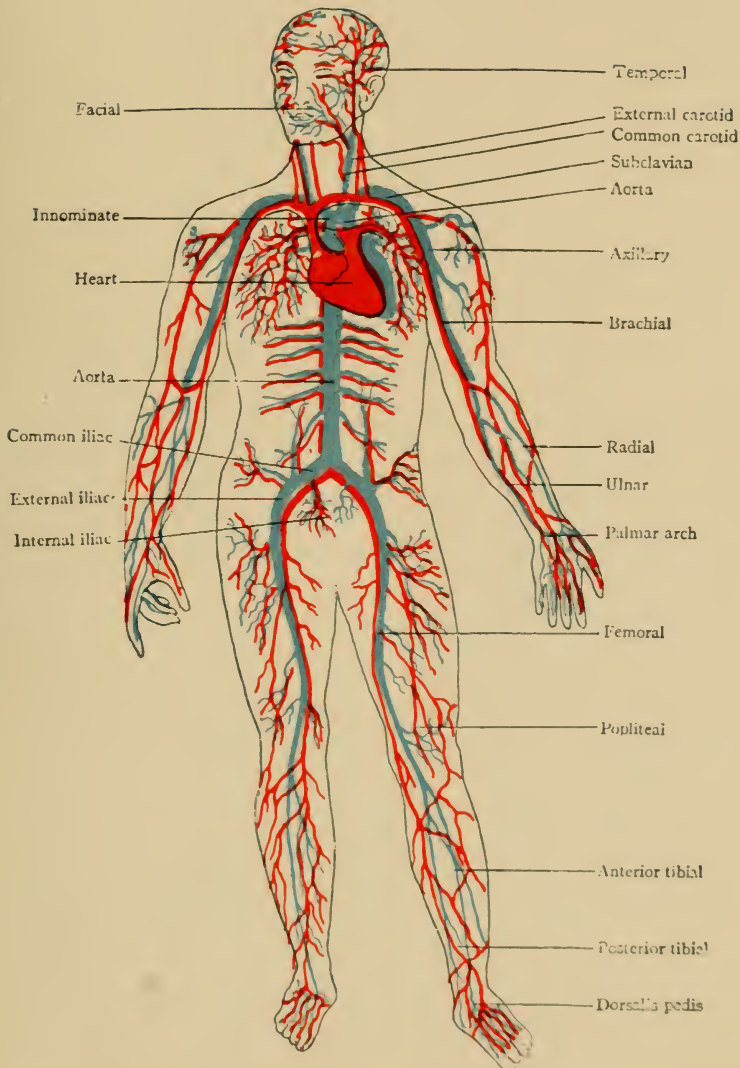
The front part of the right lung has been removed, and the pulmonary vessels and the bronchial tubes are thus exposed. (Gerrish.)

PLATE III



Valves of the Heart and Great Arteries, Viewed from Above, the Auricles having been Removed. (Gerrish.)

PLATE IV



The Principal Arteries and Veins of the Body. (Morrow.)

descending aorta. From the arch are given off the *innominate artery* which divides at once into the *right common carotid* and *right subclavian.* The *left common carotid* and *left subclavian arteries* are given off separately from the arch of the aorta. The subclavians supply the arms. The common carotids divide to form the *internal carotids,* distributed to the brain and eyes, and the *external carotids* which divide to supply with blood, the structures of the oral cavity, tongue, throat, face, and the outer part of the head. The descending aorta gives off many branches, one of which goes to the lungs to supply them with food and oxygen. The important abdominal arteries are the *celiac axis* supplying the stomach, liver, spleen, and pancreas; the *superior mesenteric* supplying the small intestine and half of the large intestine; the *inferior mesenteric* supplying the lower half of the large intestine, and the *renals* supplying the kidneys. The abdominal aorta divides at its lower end into the *right* and *left iliac arteries* which go to the legs.

The Capillaries.—The arteries divide into smaller branches, the *arterioles,* and these continue to divide until the smallest divisions, the *capillaries,* are formed. These consist of a single, flattened layer of cells, continuous with the lining of the heart and other vessels. They form an exceedingly fine network among the tissues and the only tissues lacking them are the epithelia, the cartilages, and the cornea of the eye.

The Veins.—The capillaries unite to form small *venules* which again unite to form larger and larger *veins.* Veins differ from arteries in their thinner walls, though the same tissues are present, and in the fact that valves are usually present which prevent any return flow of blood, allowing it to flow only toward the heart. In general the veins are nearer the surface than the arteries but have a similar distribution. Thus the jugular veins return the blood from the head, the pulmonaries from the lungs, etc. One notable exception is found in the *portal vein* (see Plate V), already mentioned under the liver, which collects the blood that has passed through the capillaries of the intestinal tract, carries it to the liver, and there again breaks up into capillaries among the lobules of the liver. The hepatic vein then collects the blood from both the portal vein and the hepatic artery to return it to the heart.

The Blood.—The blood may be considered a tissue in which the intercellular substance is fluid. This fluid is called the *plasma* and consists chiefly of water containing in solution the various foods and wastes as well as the peculiar substance, *fibrinogen,* which forms the clot when it escapes from the vessels. The cells are of three sorts, the red corpuscles, the white corpuscles and the platelets. The *red corpuscles* (see Plate VI) are circular, biconcave disks of protoplasm, without nuclei or cell walls, but which have the red coloring matter known as *hemoglobin* for the transportation of oxygen. These cells are very minute, $\frac{1}{3200}$ of an inch in diameter, but are so numerous that four and a half millions (in woman) to five millions (in man) are contained in a single cubic millimeter of blood. These corpuscles are continually being formed in the red marrow of the bones.

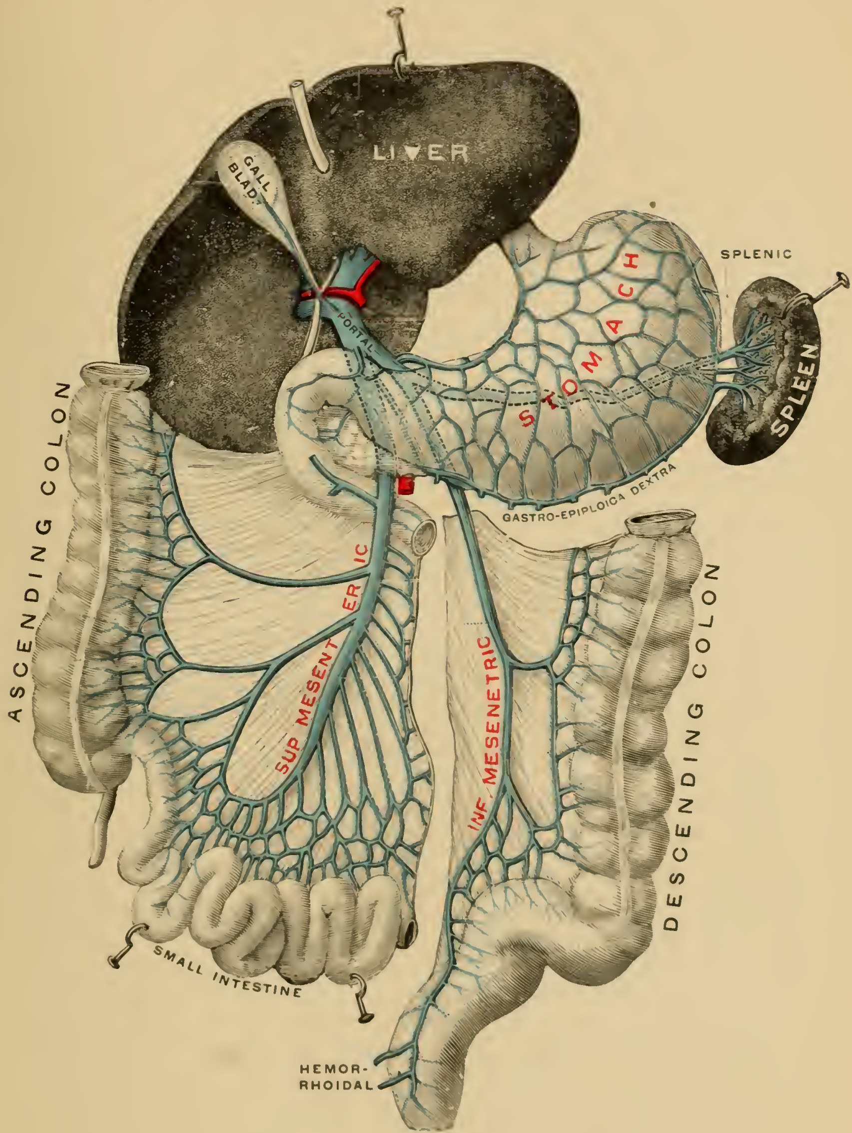
The *white corpuscles,* or *leukocytes* (Plate VI), are of several different kinds, but all agree in being slightly granular, in having nuclei and in possessing independent motion and ability to change their form (ameboid movement). They occur in the lymph and other fluids of the body as well as in the blood. They measure on an average about $\frac{1}{2500}$ of an inch and are much less numerous than the red corpuscles.

Fig. 11.—Lacteals and lymphatics during digestion.

The *blood platelets* are not well known. They are irregular in form, smaller than the red corpuscles and somewhat less numerous.

The Lymphatics (Fig. 11).—These vessels in a general way follow the same course as the veins. They carry back to the general circulation the fluid part of the blood which has escaped through the thin

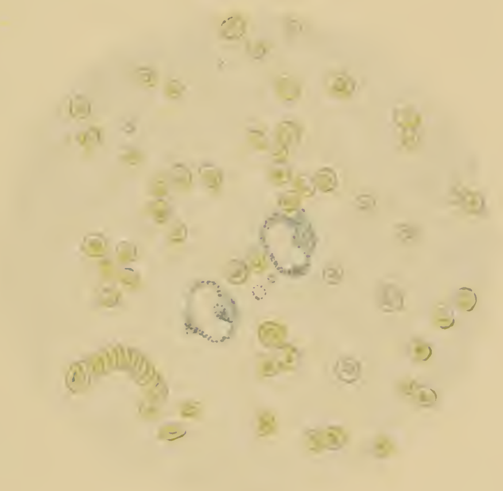
PLATE V



Portal System of Veins.

The liver is turned upward and backward, and the transverse colon and most of the small intestines are removed. (Gerrish.

PLATE VI



Normal Blood, showing Rouleaux and Leukocytes. (Musser.)

(Oc. 4, ob. 1-12 immersion.) Drawn by J. D. Z. Chase.

walls of the capillaries to bathe the cells of the various tissues. As the pressure is greater in the capillaries the fluid, once escaped, cannot return to the blood directly, but is carried back by another set of vessels. These differ but little from the veins except that they are thinner walled. The lymph itself differs but little from the plasma of the blood, except that it contains less food and oxygen and more carbon dioxide and other waste matter. There are two large lymphatic vessels which pour the lymph back into the blood by way of the jugular veins just under the collar-bones. The right vessel is small because it collects only the lymph from the right arm and shoulder and the right side of the head. The left vessel collects the lymph from the corresponding areas and also from all the lower part of the body. A large vessel, known as the *thoracic duct*, brings up to the left jugular vein all the lymph from the abdominal region and the lower limbs. The lymphatics of the intestinal region have a special function in absorbing the fatty portions of the digested food. This passes into these vessels in the form of an emulsion of a milky color, and this fact has given to the particular lymphatics carrying this fluid the name of *lacteals*. Along the line of the lymphatic vessels are found the *lymph nodes* or *glands*, in which the white corpuscles are formed. They are very numerous and widely distributed.

THE EXCRETORY SYSTEM.

The elimination of wastes formed in the body is carried on to some extent by the lungs, which remove practically all the carbon dioxide, the skin, the liver, and the intestinal epithelium, but the special system evolved for the removal of the non-volatile wastes is that known as the *excretory system*. The essential organs of this system are the *kidneys*, and the accessory organs are the *ureters*, *bladder*, and *urethra*.

The Kidneys (Fig. 12).—The *kidneys* are compound tubular glands, somewhat bean-shaped, situated on either side of the midline behind the peritoneum with the concave side (hilum) toward the midline, and the middle of each kidney is a little above the waist line. The right kidney is a little lower than the left, to make room for the liver. Each kidney is about four inches long by two broad and one in thickness, and averages about five ounces in weight. On the outside of the kidney is a tough capsule of connective tissue. Inside of this is a thick layer known as the *cortex* which is the chief secreting portion. Toward the center from this there is still another layer, the *medulla*, which is thrown up into a number of pyramidal projections, the *pyramids* of *Malpighi*. There remains a central cavity, the *pelvis* (basin) of the kidney. This chamber serves to collect the urine which is poured into it from the countless tubules. From the pelvis the urine is passed out into the ureter to be carried to the bladder.

The essential structures of the kidneys are the *uriniferous tubules* which are estimated to number about 500,000. On examination under the microscope the tubule (Fig. 13) is found to consist of an irregularly coiled portion, one part of which is a straight loop and of an inflated terminal portion, the *Bowman capsule.* This capsule contains a knot of capillary bloodvessels known as the *glomerulus.* The capsule and glomerulus together constitute the *Malpighian corpuscle.* The cavity of the capsule is continuous with that of the tubule. This latter structure is formed of glandular cells for the purpose of secretion and the cells vary somewhat in different portions of the tubule. Each tubule terminates in a *collecting tubule* which gathers the secretions from a number of the uriniferous tubules. The collecting tubules open upon the surface of the pyramids and pour the urine into the pelvis of the kidney.

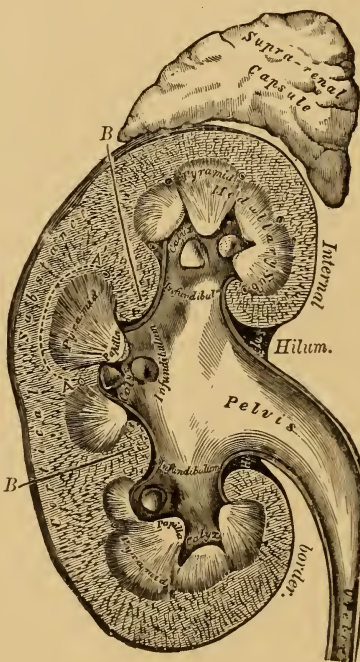


FIG. 12.—Vertical section of kidney. (Gray.)

The kidneys are abundantly supplied with blood from the *renal arteries.* After the blood has passed through the capillaries of the glomeruli and about the secreting tubules it is returned to the circulatory system by way of the *renal veins.*

The Ureters.—The ureters are the ducts of the kidneys. They are about the diameter of a goose-quill and a foot or more in length. Their walls are muscular for the purpose of forcing the urine into the bladder.

The Bladder.—The bladder is merely a reservoir for the urine. It is lined with a mucous membrane which is continuous with that of the ureters and urethra. The wall is chiefly made up of muscle and connective tissues. On the outside it is covered by the peritoneum. The

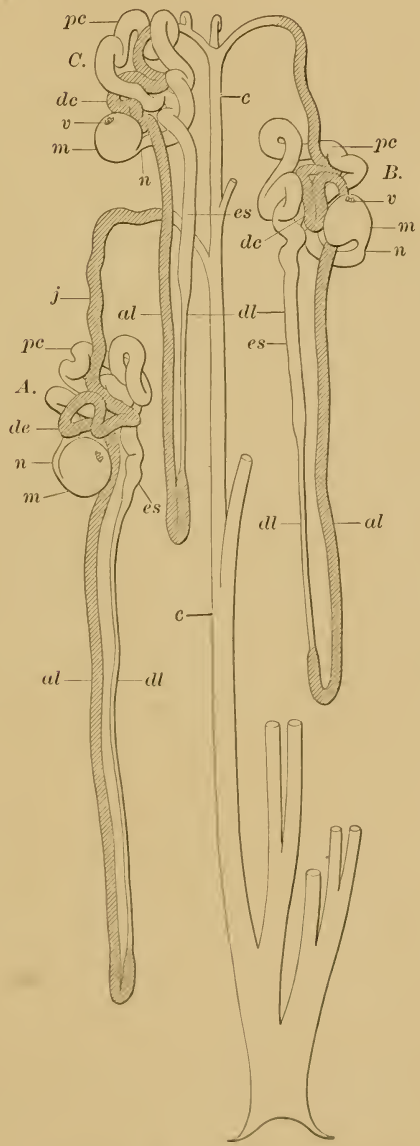


FIG. 13.—Diagram of three uriniferous tubules and their relation to a collecting tubule: *A*, beginning of a tubule, the Malpighian corpuscle of which is situated in the lowermost portion of the cortex; *B*, about the middle of the cortex; *C*, in the outer portion of the cortex; *m*, Malpighian corpuscle; *v*, vessel porta; *n*, neck; *pc*, proximal convoluted portion; *es*, end segment; *dl*, descending limb; *al*, ascending limb of the loop of Henle; *dc*, distal convoluted portion; *j*, junctional tubule; *c*, collecting tubule. (Huber.)

ureters enter the bladder near its base by a very diagonal course. At the neck of the bladder is a *sphincter muscle* which is normally closed and opens only in the act of micturition. The duct of the bladder is the *urethra.*

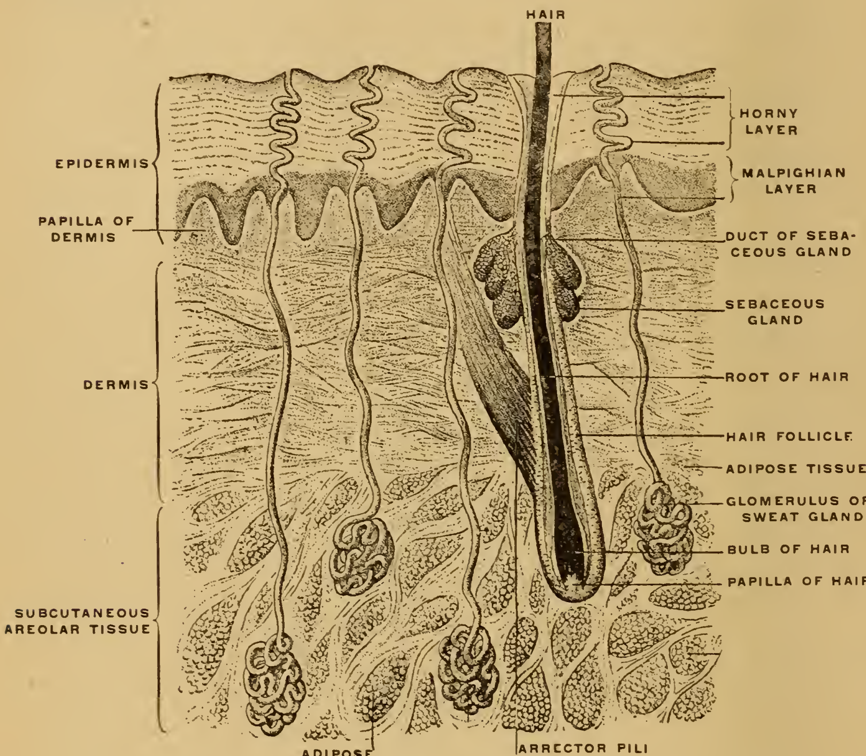


Fig. 14.—Vertical section of the skin. (Testut.)

THE SKIN.

This organ is by no means a simple structure, but consists of the following parts (Fig. 14):

1. Cuticle or epidermis.
2. Cutis or dermis.
3. Sweat glands.
4. Oil glands.
5. Hairs and nails, appendages of the skin.

1. **The epidermal tissue or cuticle** forming the outer or scarf skin consists of layers of cells that are dead on the outside and fall off continually in great numbers. These are replaced by others which are constantly being formed in the lower layer next to the cutis. The epidermis has no nerves and receives no blood, but obtains its nourishment from bloodvessels which come very close to it in the cutis and the lymph penetrates it to nourish the living cells.

2. **The Cutis.**—The cutis or inner or true skin (derma) is composed chiefly of white fibrous and yellow elastic connective tissues closely interwoven to form an extremely tough and pliable layer. In this are embedded the bloodvessels, nerves, and muscles of the skin.

3. **Bloodvessels.**—These are very numerous in the cutis. They not only serve to nourish the skin, but are of the greatest importance in aiding in controlling the temperature of the body.

4. **Nerves.**—Nerves of several classes penetrate the cutis and have their endings in the walls of the bloodvessels, in the muscles and glands, or end as sensory papillæ of touch and temperature.

5. **Muscles.**—There is not a great quantity of muscle tissue in the skin, but at the base of every hair (and even though the human body seems to be naked over the greater part of its surface there are minute hairs thickly imbedded in the skin) there is a little muscle which is able to contract and set the hair on end. In cold weather these muscles contract the skin, which is roughened on the outside as a result of the reaction of the muscles on the vestigial hairs, the phenomenon being known as "goose flesh."

6. **Sweat Glands.**—The minute glands which secrete the perspiration arise from the epidermis, but they are deeply imbedded in the cutis. They open as the microscopic pores of the skin, below which they have the form of spiral tubules and end near the lower part of the cutis in a coiled knot.

7. **Oil Glands.**—These also belong to the epidermis, though imbedded in the cutis. They are found in connection with the hair follicles. Even though the hairs are microscopic the glands are present and secrete the sebaceous matter which keeps the skin soft.

8. **Areolar Tissue.**—This tissue is composed of connective tissues similar to those which make up the cutis, but the fibers are loosely woven. This layer lies below the cutis, which it attaches more or less loosely to the organs beneath.

9. **Adipose Tissue.**—This is fatty tissue, some of which is nearly always present in the areolar tissue just below the cutis. In reality it is composed of areolar tissue, in the cells of which fat globules are stored. It occurs frequently in other parts of the body in connection with areolar connective tissue.

DUCTLESS GLANDS.

A number of glands are without ducts and deliver their secretions to the blood (ductless glands or glands of internal secretion). Although these work together to some extent in controlling the metabolism of the body, they are not usually considered as forming a system, because they are scattered about the body and usually have no connection with each other. Their secretions, called *hormones*, are chemical regulators of the body and are of such great importance that the removal of the glands is often followed by death or at least by grave disturbances in the metabolism of the body.

1. **Thyroid Gland.**—This gland lies in the neck on either side of the trachea, just at the lower end of the larynx. It is deep red in color and weighs about one ounce. Enlargement of this gland is known as *goitre*.

2. **Parathyroid Glands.**—These are two small masses of cells, about a quarter of an inch in diameter, imbedded in the surface of the thyroid. On account of their small size and their position they were not known until comparatively recently. Functionally they have nothing to do with the thyroid, but are quite separate organs.

3. **Thymus Gland.**—This organ is situated within the chest cavity, above the heart and in front of the trachea. It appears very early in fetal life, functions during childhood, but has almost entirely disappeared at puberty. At its largest it weighs about three-quarters of an ounce.

4. **The Adrenal or Suprarenal Glands.**—The adrenal or suprarenal glands are two bodies, each weighing about an eighth of an ounce, lying one above each kidney (Fig. 12). In addition to gland cells they contain much nervous tissue.

5. **The Hypophysis or Pituitary Body.**—The hypophysis is lodged within the skull beneath the midbrain, to which it is attached.

6. **The Spleen.**—The spleen is the largest of the ductless glands. It is situated behind the stomach on the left side of the body. It has a dark red color and weighs from five to eight ounces. This gland also varies according to age, being larger in youth. It is well supplied with blood and contains a large amount of lymphoid tissue. After prolonged attacks of malaria the spleen becomes permanently enlarged, forming the condition known as "ague cake."

Other ductless glands, which are minute and which are little known as far as their functions are concerned, are the *pineal body* arising from the roof of the midbrain, the *coccygeal gland* near the tip of the coccyx and the *carotid glands* situated at the upper ends of the common carotid arteries.

While the above glands apparently function only as ductless glands, there are other structures in the body, which, in addition to other functions, secrete hormones to the blood. Among these are the *liver*, the *pancreas* (islands of Langerhans), the *reproductive organs*, the *lymph glands*, and the *mucous membrane* of the *intestinal wall*.

THE SKELETAL OR SUPPORTING SYSTEM.

In the broadest sense this includes all the supporting structures of the body, which fall into the following classes:

1. Fibrous connective tissues.
2. Tendons.
3. Ligaments.
4. Cartilages.
5. Bones.

The skeleton proper consists of the bones and the cartilages connected with them, but the connective-tissue fibers that bind together the soft cells of other tissues are just as truly supporting in their function and form for those tissues a skeletal structure that is just as real as is the bony framework for the body as a whole.

1. **The Connective Tissues.**—The connective tissues have already been described as consisting of white inelastic and yellow elastic fibers which are interlaced among the cells of other tissues all over the body except in the epithelium, and even in this case we find that the cells are underlaid by a structure, known as the basement membrane, formed by connective tissue.

2. **Tendons.**—Tendons have already been mentioned as forming the connection between muscles and the structures which they move.

3. **Ligaments.**—Ligaments consist of bundles of inelastic fibers and serve to bind the bones together at the joints and to hold other organs, as the liver and ovaries, in place.

4. **Cartilages.**—Cartilages or gristles as they are more commonly called, are characterized by their tough, elastic nature. They are known as (1) *hyaline*, when pure; (2) *fibrocartilage*, when mixed with white fibrous tissue; and (3) *yellow elastic cartilage*, when mixed with yellow elastic fibers.

As a rule the cartilages are disposed in certain definite relations to the bones, either between the joints to absorb shock, which is the usual arrangement, or as in the attachment of the ribs to the sternum to permit the expansion of the thorax in inspiration. They are also found in the external ear and the tip of the nose, and the sternum is pieced out at its lower end by the xiphoid cartilage. Rings of cartilage are present in the trachea and bronchi, as already stated, to keep these passages open.

Skeleton (Fig. 15).—The skeleton or bony framework consists of about 206 to 208 bones. The number varies within narrow limits because certain small bones may be present or absent without making any apparent difference in the efficiency of the structure.

Bony tissue is made up of bone cells, between which there is an intercellular substance of organic matter impregnated with lime salts for the sake of rigidity. In young children the bones are somewhat pliable, but in older persons they become very rigid, owing to the increasing deposition of lime. Bone tissue is permeated by blood-vessels, just as other tissues are, for nourishing the cells.

Around the outside, except in the joints, there is a tough connective-tissue layer called the *periosteum*.

Bony tissue may be *compact* or it may be *spongy* (cancellous). Compact bone is found in the shanks of the long bones, such as those of the arms and legs, and in the outer layer of all other bones. Spongy bone forms the mass of the heads of the long bones, the vertebræ and ribs, the middle layers of the skull, and so on. The cavities in the middle of the long bones are filled with *yellow marrow*, a fatty deposit, while the small spaces in spongy bone are filled with *red marrow* within which the red blood corpuscles are manufactured.

5. **Bones.**—The bones fall naturally into two classes, the *axial skeleton* and the *appendicular skeleton.* The former class includes the bones of the head, spinal column, ribs and sternum, while the latter class consists of the bones of the limbs.

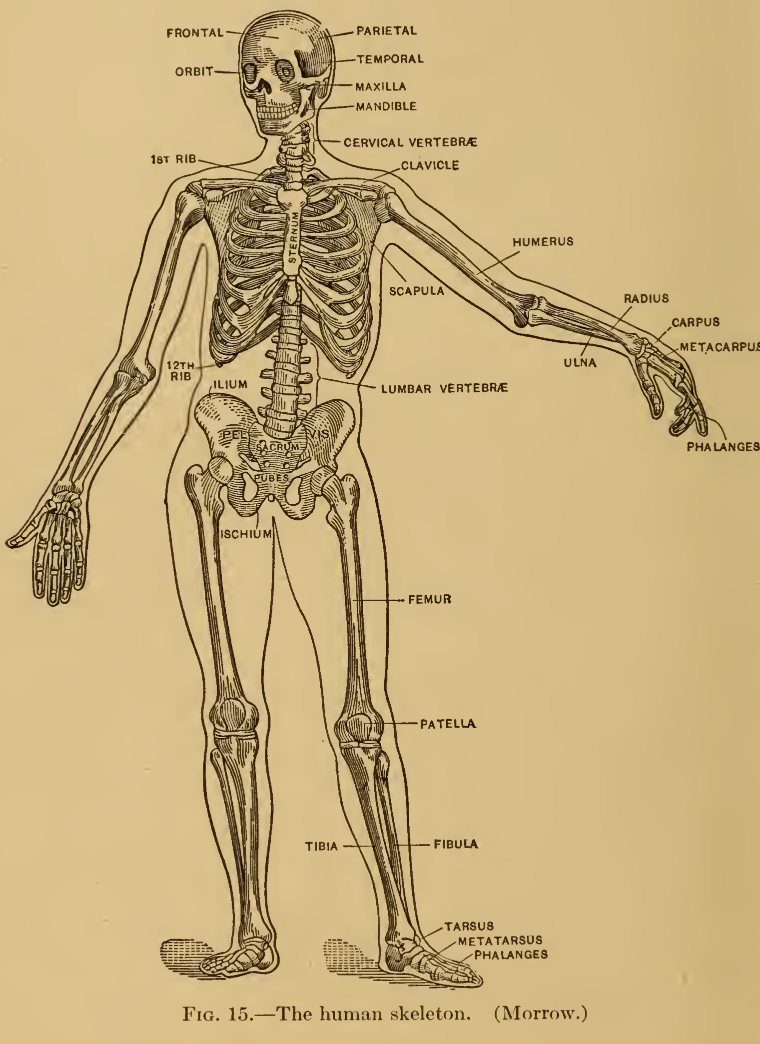


Fig. 15.—The human skeleton. (Morrow.)

The *bones of the head* include those of the cranium or brain-case, 8 in number, *occipital*, *parietal* (2), *frontal*, *temporal* (2), *sphenoid* and *ethmoid*; those of the *face*, 14 in number, *nasal* (2), *lacrimal* (2), *vomer*, *malar* (2), *palate* (2), *turbinated* (2), *maxilla* or upper jaw (2), and *mandible* or lower jaw; the *ear bones,* three pairs in number, *malleus* (2), *incus* (2), and *stapes* (2); and the *hyoid* at the base of the tongue. Most of these are more or less immovably locked together, the only movable ones being the mandible, the hyoid, and the ear bones.

The bones of the *spinal column* are 31 in number, arranged as follows: 7 cervical or neck vertebræ; 12 *dorsals* in the thoracic region; 7 *lumbars* in the lumbar region; 5 *sacrals* in the pelvic region; and 4 *coccygeals* forming the coccyx or rudimentary tail. The first two cervical vertebræ are specially modified, the first or atlas to form the connection with the base of the skull and the second or axis to form a special kind of joint with the first to allow the head to be turned. The dorsal vertebræ all bear ribs attached to their transverse processes. The lumbar vertebræ are free from ribs or other special modification. They are the largest of the vertebræ and their processes are well developed for the attachment of muscles. The sacral vertebræ are fused into a single mass to afford better attachment for the other bones of the pelvis to which the legs are joined. The cocygeal bones are more or less vestigial vertebræ, varying somewhat in number, but usually four. The bones of the spinal column are all capable of being moved except those of the sacrum and, to some extent, the coccyx.

The *sternum* or breast-bone protects the main organs of circulation and respiration. It consists of three parts which are slightly movable. To the upper portion, which is short, are attached the collar bones and the first pair of ribs. The body of the sternum has the cartilaginous portions of other ribs attached to it down to and including the seventh rib. The xiphisternum, xiphoid process, or ensiform process, as it is variously called, is the free portion of the sternum projecting downward over the stomach. In younger years it is cartilaginous, but becomes more or less ossified in later life.

The *ribs* are bony arches, 12 in number, which support the thoracic wall and protect the organs of circulation, respiration, and to some extent the upper abdominal organs. The first seven pairs, called true ribs, are attached directly to the sternum by continuations of hyaline cartilage. The next three, called false ribs, are attached in front, each to the cartilage of the next rib above. The last two pairs, the floating ribs, are not attached at their anterior ends. The ribs are all attached to the vertebræ by movable joints, so that in respiration they can be rotated outward and upward, and the costal cartilages, by which they are attached to the sternum, permits the expansion of the anterior thoracic wall.

In the *appendicular skeleton* the framework of the upper extremity consists of 32 bones: the shoulder-blade or *scapula*, the collar-bone or *clavicle,* the *humerus* in the upper arm, the *radius* and *ulna* in the forearm, 8 *carpal* bones in the wrist, 5 *metacarpals* in the hand, and 14 *phalanges* in the fingers. In the lower extremity the bones have much the same arrangement. On either side is one large irregular shaped bone, the *innominate*, to form the sides of the *pelvis*. These are firmly united behind to the sacrum and to each other in front. In the leg are 30 bones: the *femur* or thigh bone, the *patella* or knee-cap, the *tibia* and *fibula* or large and small shin bones, 7 *tarsal* bones in the ankle, one of which is the heel-bone, 5 *metatarsals* in the instep, and 14 *phalanges* in the toes.

Joints.—Bones are attached to each other by joints which we may classify in the following manner:

1. Immovable joints.
2. Slightly movable joints.
3. Freely movable joints.

Of the *immovable joints* there are two chief types. *Sutures*, such as are found between the bones of the skull, are formed by the interlocking of irregular edges of adjoining bones, and *symphyses*, or joints in which the bones are closely united by connective tissue, as between the innominate bones in the front of the pelvis. Both sutures and symphyses often become completely ossified in adult life, but in younger years they allow the parts to yield slightly.

Slightly movable joints are found between most of the vertebræ of the spinal column. Here pads of fibrocartilage, the intervertebral cartilages, are inserted between the vertebræ and allow the column to bend in any direction by the compression of the cartilages.

Movable joints are those in which the bones slip or rotate past each other in motion. The articular surfaces of the bones forming such joints are covered with hyaline cartilage and between the bones is found a closed sac, the *synovial membrane*, which secretes a slippery fluid to prevent friction. There are a number of classes of these.

1. *Gliding joints*, in which the articular surfaces are nearly flat and the bones slip past each other slightly, as in the articular processes of the vertebræ and the bones of the wrist and ankle.

2. *Hinge joints* are those which permit of motion in only one plane as in a hinge. Examples are found in the elbow, knee, and between the phalanges of the fingers and toes.

3. *Ball-and-socket joints*, in which the rounded head of one bone is received into a cup-shaped cavity, as in the attachment of the humerus at the shoulder and that of the femur to the pelvis. This permits of motion in any plane.

4. *Torsional* or *pivot joints*, which permit one bone to rotate against another. One such joint occurs between the first and second cervical vertebræ to permit the turning of the head. Another is found in the forearm where the radius twists about the ulna in turning the hand over. The ulna is unable to twist on account of its mode of attachment to the humerus, and the hand is attached to the radius which twists around the ulna.

5. *Saddle joints* are formed by bones whose articular surfaces are concave in one direction and convex in the other. Such bones fit together like a man in a saddle and allow free movement in any direc-

tion, as in the attachment of the metacarpal bone of the thumb to the wrist.

6. *Sliding hinge.*—There is only one pair of these in the body, at the articulation of the mandible to the temporal bone. In opening the mouth the lower jaw not only acts like a hinge, but the head or condyle of the mandible slides forward in its fossa or socket. The jaw can be shoved forward, backward, and sidewise.

Levers.—The levers formed by the movable bones of the body are for the operation of the joints by muscular stress. According to the principles of physics they fall into the groups, known as levers of the first, second, and third classes, according to the position of the weight to be moved and the point of application of the power which moves it.

Arches.—The skeleton as a whole consists of a series of curves and arches. These give greater elasticity to the framework and help to absorb shock. So elaborate is this arrangement that no bone is without its curved surfaces and the plan is carried out even in the internal structure of the bone.

The greater curves of the body are found in the arches of the feet which are of the greatest importance in preventing shock in walking, in the structure of the pelvis which consists of a series of arches, and in the curves of the spinal column. Any shock in walking which might be carried upward through the body tends to be shunted off by every one of these larger curves as well as by the innumerable smaller ones, before it can be communicated to the skull and the brain. Since there are twenty-two of the intervertebral pads in the spinal column, in addition to the curves, it is evident that here is a splendid structure for preventing the transmission of shock.

THE MOTOR OR MUSCULAR SYSTEM.

The cells of the body which are specialized for contraction make up the muscle tissue. The function of these cells is to bring about motion by shortening their length. This motion may be concerned with the internal affairs of the body, as of the heart in circulation, the intestinal wall in peristalsis, the arterioles in controlling the flow of blood, etc., or it may be related to outside matters, as in the movements of the eyeballs, or the hands, or it may take the form of locomotion. As these movements are not all of the same character, some differentiation of the contractile tissues is to be expected. In the evolution of the higher animal three distinct kinds of muscle cells have arisen for particular uses.

1. *Non-striated*, or smooth muscle, not under control of the will.

2. *Cardiac* or heart muscle, a special kind found only in the heart and also involuntary.

3. *Cross-striated* or striped muscle, often known as voluntary muscle, although there are certain of these muscles such as the diaphragm and intercostals, used in breathing, which are only partially

under the control of the will, and any of them, under certain conditions, may become involuntary in action.

The *smooth muscle* is the most primitive type in man and occurs commonly in lower forms, many of which have no other kind. The cells of this tissue (Fig. 16) are small and spindle-shaped, with the nucleus at the center, without cell walls, and the cytoplasm is faintly striped in a lengthwise direction, a characteristic of all contractile tissues. Cells of this type occur in the intestinal wall, in the ducts of glands, the ureters, the blood and lymph vessels, the iris of the eye, the skin, etc. They are very slow in movement in comparison with other types of muscle tissue. There are no tendons in connection with this sort of muscle, since it usually lies in the walls of tubes, the sizes of which can be controlled by their contraction. The cells are intermingled with connective tissues.

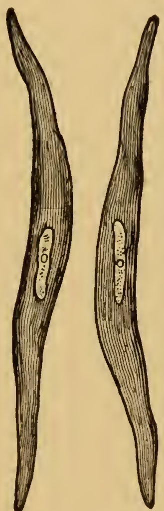


Fig. 16.—Fiber cells of plain muscular tissue (highly magnified). (Kimber.)

The heart or *cardiac muscle* cells differ in being block-like in form, often branched, with a central nucleus and a faint cross-striation. They also have no cell walls. In some respects this type is intermediate between the other two, yet with special characters of its own. There are some tendons in connection with the heart muscle, particularly the *chordæ tendonæ* which hold the valves of the heart in place during contraction. The heart muscle has the special property of automatic action.

Cross-striated muscle (Fig. 17) is highly specialized for rapidity of contraction. The cells are in the form of long threads, sometimes several inches in length, which end rather bluntly. There is a definite cell wall known as the *sarcolemma*. The nuclei are very numerous and are scattered over the cytoplasm immediately under the sarcolemma. The cytoplasm is much more highly differentiated than in either of the other kinds, and we find not only the lengthwise striation much more definite, but there is also a very definite cross-banding of the contractile substance. This character seems to be connected with rapidity of action. When such a muscle fiber is subjected for a time to the action of alcohol, it tends to split lengthwise into much more delicate threads called *fibrillæ*. When treated with acid the cell substance readily breaks crosswise, forming what are known as *Bowman's disks*.

Contractile tissues are very widely distributed throughout the body, though we are not aware of the action of many of them when they contract, for example, those in the skin, bloodvessels, intestinal tract, etc. When these tissues are aggregated into definite masses they are referred to as *muscles*. But muscular tissue is not always so distributed; in fact the non-striated type is generally distributed in the form of sheets or layers, such as those we find in the walls of the bloodvessels and the intestine where they form continuous layers throughout these structures. Even in the heart, though there are four chambers, the muscles which govern these are more or less continuous.

The great mass of striated muscle tissue, which makes up so large a part of the limbs and of the body wall and which is usually to a greater or less extent under the control of the will, is characteristically divided into definite muscles. In size these aggregations range from

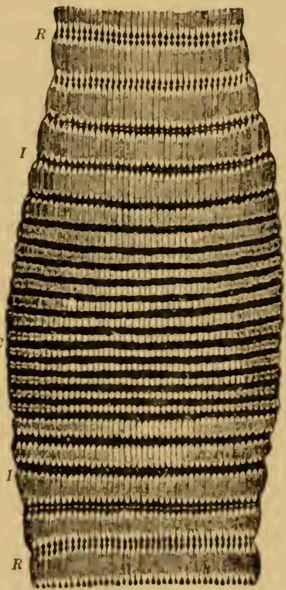


FIG. 17.—Wave of contraction passing over a muscular fiber of dyticus. (Very highly magnified.) *R*, *R*, portions of the fiber at rest; *C*, contracted part; *I*, *I*, intermediate condition. (Schaefer.)

the almost microscopic muscles which move the tiny ear ossicles, to the large muscles of the limbs. In form they are extremely variable, in adaptation to the spaces they occupy and the functions they perform. As a rule muscles show the parts known as the belly, origin, and insertion. The *belly* is the swollen portion such as is seen in a long muscle like the biceps, for example, though it is usually not so well marked as in this case. At each end such a muscle tapers off into the tendons by which it is attached. The attachment at the stationary end is known as the *origin* of the muscle, and that upon the part to be moved as the *insertion*.

Such muscles are usually arranged in pairs on opposite sides of the parts they are concerned in moving. Thus the biceps lies on the front of the arm and the triceps on the back of it and they are inserted into the bones of the forearm which they move. There are numerous departures from this rule, however, and certain muscles even lie free without any relation to the skeleton, such as the diaphragm, the cheek muscles, and those of the lips and eyelids. Altogether there are about five hundred separate voluntary muscles.

If we examine a cross-section of a muscle we will find on the outside a connective-tissue layer forming a binding membrane called the *fascia* or *perimysium*. Strands of similar tissue run inward from this, dividing the muscle into large portions which are again subdivided until the *muscle bundles*, consisting of a number of muscle fibers, are formed.

The tendons originate among the connective tissue between the muscle cells.

THE NERVOUS SYSTEM.

This system has the function of correlating the activities of all the other systems of the body, as well as of relating the body to the outside world by means of the special senses. Therefore we naturally expect to find nervous tissues widely distributed throughout the body.

The essential structure of the nervous system consists of the *nerve cells* or *neurons* (Fig. 18). Each neuron is made up of a *cell body* with at least two processes or *nerve fibers* which are merely extensions of the cell. As a rule one of these nerve fibers is longer than the other and is known as an *axon*. The cell bodies are aggregated into masses called *ganglia*. The "gray matter" of the brain and spinal cord consists of large numbers of these nerve cells, while the "white matter" consists of the nerve fibers. The fibers are often collected into bundles for convenience of distribution, such bundles of fibers being called *nerves*.

Nerve cells originate impulses and also receive them from the sensory endings or from other nerve cells. The nerve fibers are highly specialized for the purpose of transmission of the impulses. The apparatus is often compared with a telegraph system in which the ganglia represent the offices where messages are received and sent out and the nerve fibers represent the wires which can only carry the messages sent over them.

Neurons communicate with each other by having their processes in close contact, though they do not form a continuous network, as was formerly supposed. One nerve fiber at its end is divided into branches called *terminal arborizations,* and these are closely associated with the endings of branches or dendrites of other cells. An impulse travels in only one direction along any one nerve fiber in the body, and in passing from one cell to another it goes outward through the axon, over the terminal arborizations, to the dendrites of the other cell and on to the cell body. This process is not reversible.

Nerve fibers are classified according to the direction in which they carry impulses.

1. *Afferent fibers* are those which conduct impulses from without toward their respective cell bodies. A fiber carrying impulses from

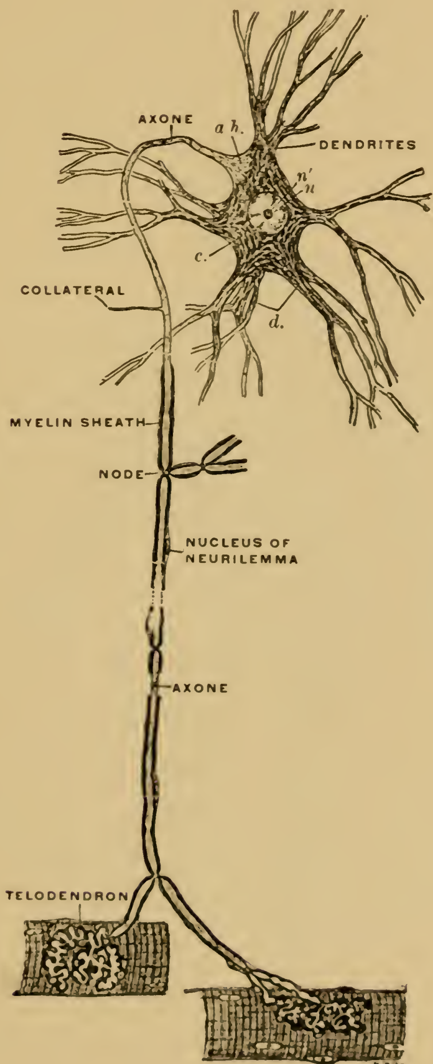


FIG. 18.—Scheme of central motor neuron. (I. type of Golgi.) The motor cell body, together with all its protoplasmic processes, its axis-cylinder process, collaterals, and end-ramifications, represent parts of a single cell or *neuron*. *a.h.*, axon-hillock devoid of Nissl bodies, and showing fibrillation; *c.*, cytoplasm showing Nissl bodies and lighter ground substance; *n'*, nucleolus. (Barker.)

the skin to the central nervous system would be an afferent fiber. The nerves of special sense all belong to this class.

2. *Efferent fibers* are those which conduct impulses away from the cell bodies, such as those going to the muscles or glands to govern their action.

3. *Commissural fibers* are those which run from one nerve cell to another.

A nerve usually consists of both afferent and efferent axons or fibers, which are bound together in one bundle for convenience in distri-

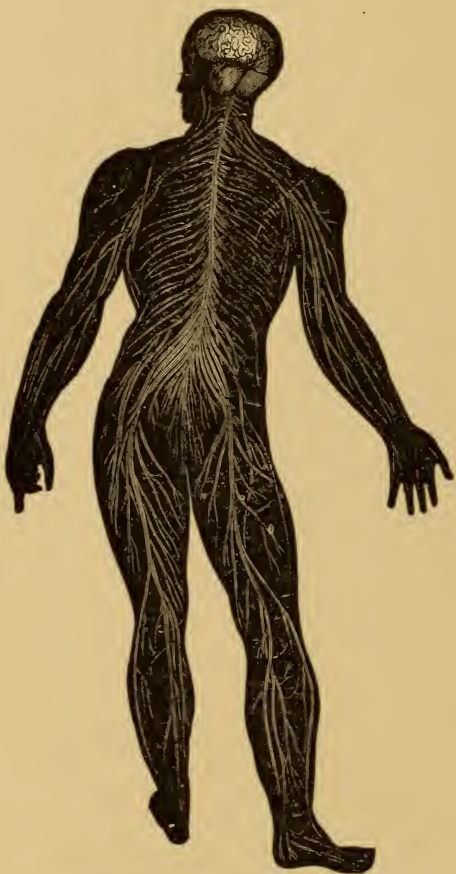


Fig. 19.—Diagram illustrating the general arrangement of the cerebrospinal system. (Kimber.)

bution, since every part of the body requires both afferent and efferent connections. When nerve fibers pass out to any distance from the ganglion they usually have a special coat or sheath called the *medullary sheath.* Such nerve fibers are said to be *medullated* to distinguish them from the *non-medullated* which lack the sheath. The longest nerves in the body are those which go to the extremities. The fibers which are distributed to the fingers and toes have their cell bodies in the spinal cord.

The nervous system consists of two chief parts:

1. The *central* or *cerebrospinal system.*
2. The *sympathetic system.*

The Central System.—The central system is made up of the ganglionic or cellular masses of the brain and spinal cord (Fig. 19), together with the axons or fibers belonging to these cells. The principal parts of this system are the brain, the spinal cord, the cranial nerves and the spinal nerves.

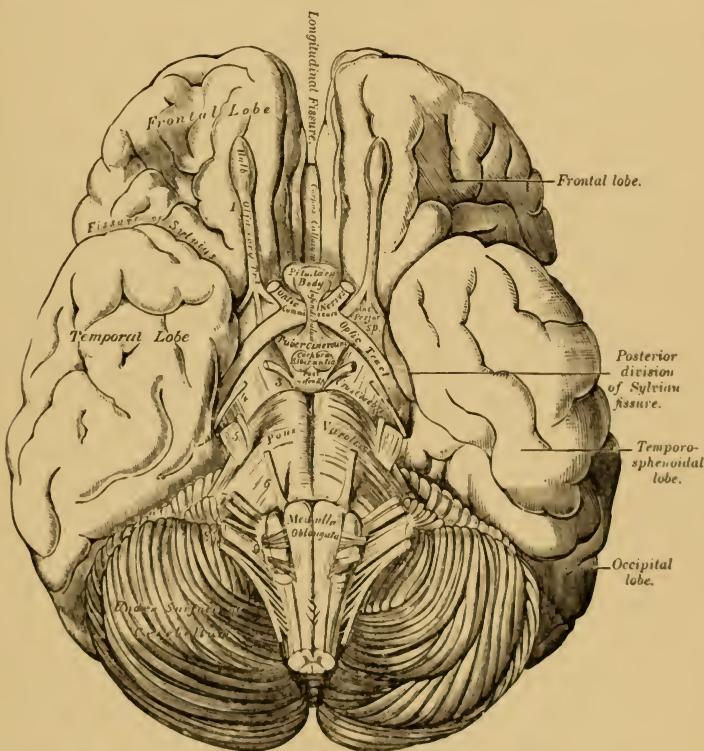


FIG. 20.—Base of brain, showing superficial origin of cranial nerves. (Little.)

The Brain (Fig. 20).—The brain consists essentially of great masses of cells or ganglia (the gray matter) with their commissural fibers and the fibers connected with the cranial nerves and spinal cord. It is protected within the skull and is further surrounded by three connective-tissue membranes. These are known as the *dura mater*, lining the bones of the cranial cavity; the *pia mater*, a delicate membrane closely covering the surface of the brain and richly supplied with bloodvessels; and the *arachnoid* which is between the other two.

The largest part of the brain is the *cerebrum* or forebrain, which fills the whole upper part of the skull. Its surface is deeply and irregularly convoluted and it is nearly separated into *right* and *left hemispheres* by a deep furrow, the *median fissure.* At the bottom of the fissure, however, there is a broad band of commissural fibers called the *corpus callosum.*

The next largest portion is the *cerebellum* or little brain situated behind and beneath the cerebrum. It is only about one-seventh as large as the cerebrum. Its surface is regularly convoluted and it is divided into a median and two lateral lobes. A broad band of commissural fibers crosses below to place the two lateral lobes in connection. This band is known as the *pons Varolii* (bridge of Varolus).

The *medulla oblongata* is that portion of the brain which is continuous with the spinal cord. It is situated beneath the cerebellum immediately behind the pons Varolii.

The cavities within the brain, known as *ventricles,* are expansions of the minute canal which runs all the length of the spinal cord.

There are twelve pairs of nerves, the *cranial nerves,* connected with the brain. Three of these are devoted entirely to special senses. The first pair, the *olfactory nerves,* have to do with the sense of smell; the second pair are the *optic nerves* or nerves of sight; and the eighth pair are the *auditory nerves* or nerves of hearing. The third, fourth, sixth, seventh, eleventh, and twelfth pairs are motor nerves distributed to certain muscles of the head. The fifth, ninth, and tenth are mixed. All these are distributed to the head, except the tenth (*vagus* or *pneumogastric nerve*), which sends fibers to the esophagus, heart, and stomach as well. The cranial nerves emerge from the skull through openings called *foramina.*

The Spinal Cord.—This is the portion of the central nervous system lodged within the spinal column and it is in direct continuation with the brain. It is not as long as the column, but tapers off and ceases at the level of the second lumbar vertebra. The same three protecting membranes which surround the brain are continued down around the cord. The cord is deeply grooved in front and behind and so is nearly separated into right and left halves, and the middle is penetrated by a tiny canal, the *central spinal canal,* which is continuous with the ventricles of the brain.

The spinal nerves number 31 pairs arranged as follows:

8 cervical nerves in the neck region.
12 dorsal nerves, corresponding to the dorsal vertebræ.
5 lumbar nerves, corresponding to the lumbar vertebræ.
5 sacral nerves, corresponding to the sacral vertebræ.
1 coccygeal nerve, corresponding to the first coccygeal vertebra.

The spinal nerves pass out through *foramina* or openings between the vertebræ, but the lower ones run for some distance down the vertebral canal before they emerge. Each spinal nerve has two roots, a dorsal and a ventral, which merge into one nerve before passing out of the vertebral canal. The *dorsal root* is made up of *afferent* (sensory) fibers only and bears a ganglion through which every incoming sensory impulse must pass before it enters the cord. The *ventral root* consists of *efferent fibers* only. After the nerves emerge from the column

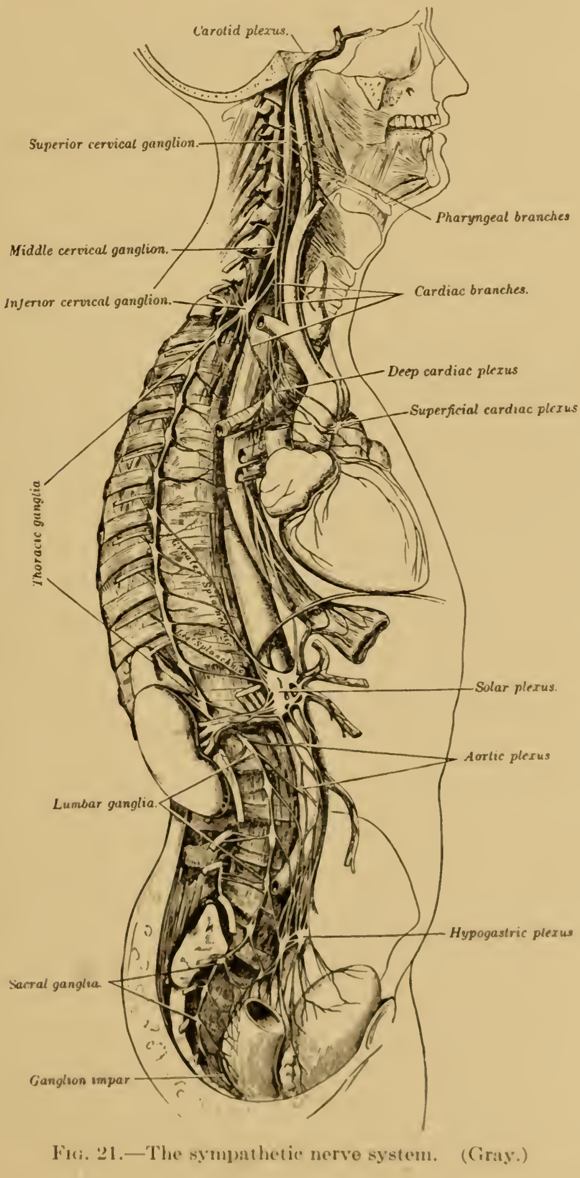


FIG. 21.—The sympathetic nerve system. (Gray.)

they often send off connecting branches to other nerves to be mingled with them in their distribution. This blending is known as a *plexus*.

The gray or ganglionic matter of the cord is centrally located. The rest of the cord is made up of nerve fibers, most of which run up or down the cord.

The first branch of a spinal nerve communicates with a ganglion of the sympathetic system.

The Sympathetic System.—This consists especially of a double chain of ganglia (Fig. 21), one chain on either side of the spinal column in the back of the thoracic and abdominal cavities. In addition to these ganglia there are other smaller ones in the heart, intestine, etc., which are connected with the chains. The sympathetic system is of the greatest importance in governing the so-called vital functions of the body. Its nerves are distributed widely over the body, to all the organs of the thorax and abdomen, to the brain and eye, and to all the bloodvessels of the body. These latter nerves are of two classes, the *vasoconstrictor* and *vasodilator*. These have the important function of regulating, by their action on the muscles, the size of the bloodvessels and consequently the distribution of the blood.

Nerve Endings.—The endings by which the neurons communicate with each other have already been discussed. The efferent nerves, which run out to the various tissues, have different endings according to the sort of cells they stimulate. In the voluntary muscles they form end-plates on the cells. In other cases they may end as fine fibrils, etc. The afferent nerves which have their sensory endings in the skin or other organs, or the organs of special sense, end in a number of ways. In the skin, for example, are found delicate fibrillar endings, sensory papillæ, etc.

CHAPTER II.

SPECIAL ANATOMY.[1]

By ROBERT H. W. STRANG, M.D., D.D.S.

THE SKULL.

The twenty-two bones that enter into the formation of the osseous framework of the head are united by immovable joints, the lower jaw excepted, called sutures. These form a strong supporting and protecting structure termed the skull. This may be conveniently studied under four headings (*a*) the cranium; (*b*) the base; (*c*) the lateral aspect; (*d*) the anterior aspect or face.

The Cranium.—The cranium comprises that portion of the skull which contains the brain. It is formed by the union of eight bones. In outline it is somewhat egg-shaped and presents for study a superior surface, forming the *vertex* of the skull, and an inferior surface.

The *external surface of the vertex* is convex and is covered in the living subject by the tissues that form the scalp. This convexity of surface is ideal for the resisting and warding off of blows. This surface is traversed by three sutures arranged in the form of the letter "H." The anterior cross suture which is situated well toward the top of the skull is called the *coronal;* the one passing from this to the posterior cross suture is the *sagittal;* the posterior transverse suture is the *lambdoid*.

The *internal surface of the vertex* is concave and is marked with elevations and depressions for the accommodation of the irregular brain surface. Through the center, running anteroposteriorly, is a groove in which lies the superior longitudinal sinus, a blood channel performing the function of a vein and carrying part of the return blood from the brain. To the margins of this groove are attached some of the supporting membranes of the brain.

The *inferior surface of the cranium* corresponds to the cerebral surface of the base of the skull (Fig. 22). It is divided by two transverse ridges into three planes, arranged like terraces with the anterior one on the highest level. These planes bear the name of *fossæ* and are called according to their position, anterior, middle and posterior. Their surfaces are more or less irregularly concave, grooved to accom-

[1] Bibliography: Gray's Anatomy; Cryer, Internal Anatomy of the Face; Deaver, Special Anatomy of Head and Neck; Swan, Manual of Anatomy; Noyes, Dental Histology and Embryology; Chapter on Anatomy of the Teeth, by C. R. Turner, in Johnson's Operative Dentistry.

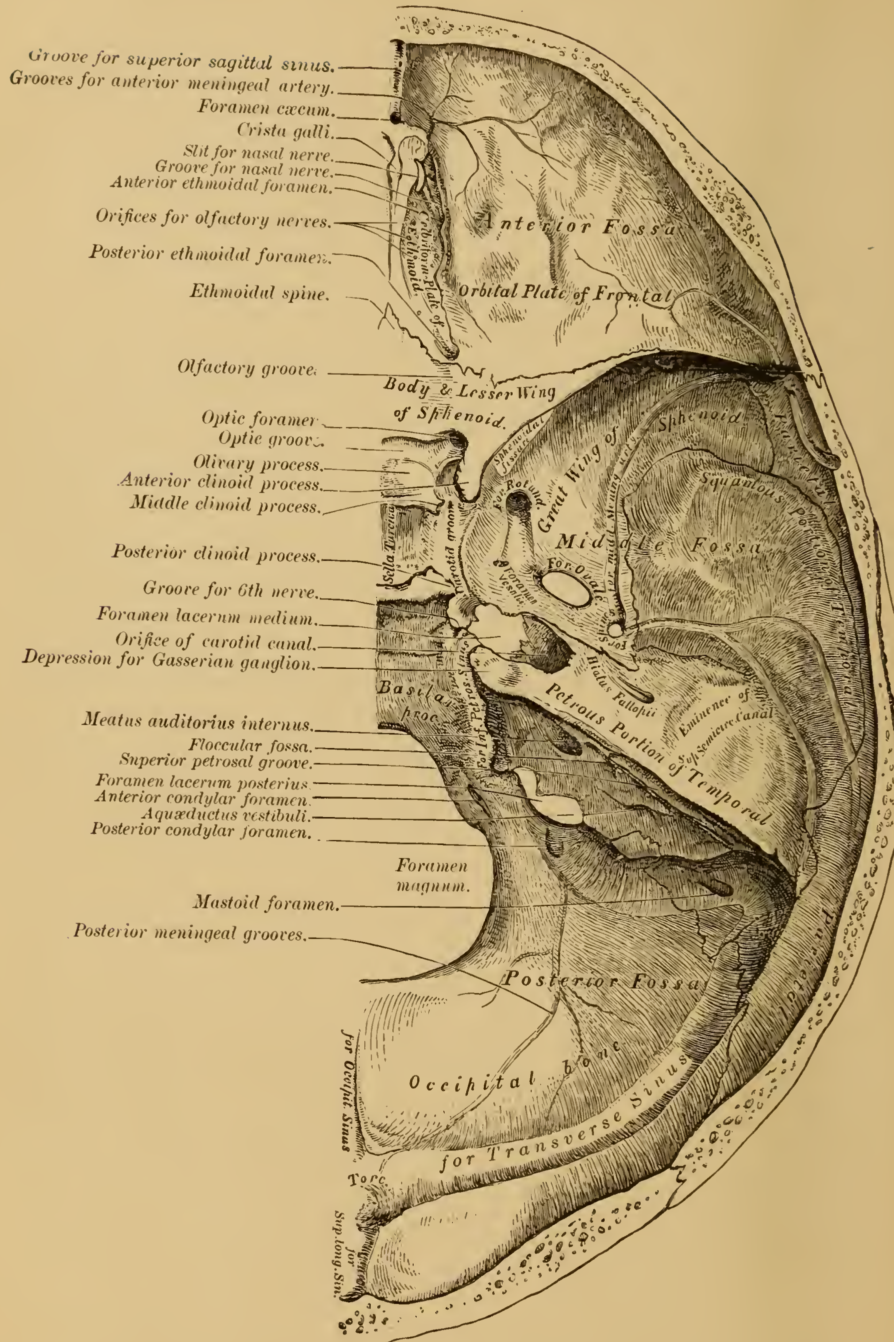


Fig. 22.—Base of the skull. Inner or cerebral surface. (Gray.)

modate bloodvessels and perforated in many places to allow these vessels and also nerves to pass in and out of the cranium.

Description of the Fossæ.—Anterior Fossa.—The points of interest in this fossa are (*a*) the prominent bony spine in the median line called the *crista galli* (cock's crest); (*b*) near the front end of this on either side, slit-like openings for the passage of the *nasal nerves* into the nasal cavity; (*c*) the cribriform plate of the ethmoid bone placed on a somewhat lower level than the rest of the floor of the anterior fossa forming what is known as the *olfactory groove.* This groove is divided anteroposteriorly by the crista galli, accommodates the olfactory bulb of the brain and has its floor pierced with many openings for the passage of the olfactory nerves to the nasal cavities; (*d*) the anterior and posterior ethmoidal foramina, situated at the outer edge of the cribriform plate, the former at about the middle and the latter at the posterior end of the plate. The bone forming the floor of the anterior fossa roofs over the orbital cavities.

Middle Fossa.—In the middle fossa are seen (*a*) two openings that communicate with the orbits. The smaller of these is the *optic foramen*, transmitting the optic nerve and ophthalmic artery to the eye; the larger one is the *sphenoidal fissure* or *anterior lacerated foramen*, for the passage of four cranial nerves, a sympathetic nerve, arteries and veins to and from the orbits; (*b*) in the center of the fossa a bony formation that resembles a saddle and for this reason is called the *sella turcica* (Turkish saddle); (*c*) on either side of this, four openings. The two anterior ones are of particular interest because through them pass the divisions of the fifth cranial nerve that go to the upper and lower teeth. The anterior opening is the *foramen rotundum* and it transmits the superior maxillary division of the fifth nerve. Behind this is the *foramen ovale* through which passes the sensory and motor portions of the inferior maxillary division of the same nerve. The largest of these four foramina is called the *middle lacerated foramen.* This is closed in the living subject with cartilage. On its posterior wall, however, is seen (*d*) the inner opening of the carotid canal through which the internal carotid artery gains entrance to the cranium.

The bone at the posterior aspect of the middle fossa acts as the roof for the middle and internal divisions of the ear and is somewhat irregular in conformation with their make-up.

Posterior Fossa.—The surface of this fossa is deeply concave and accommodates the cerebellum. It is marked with (*a*) grooves for the lateral sinuses carrying return blood from the brain. To the edges of these grooves is attached the membrane supporting the cerebellum. (*b*) The foramen magnum, centrally located, through which passes the spinal cord; (*c*) the anterior condyloid foramina for the passage of the hypoglossal nerves to the tongue; (*d*) the jugular or posterior lacerated foramina which affords a means of exit to the ninth, tenth and eleventh cranial nerves as well as the lateral sinuses; (*e*) the

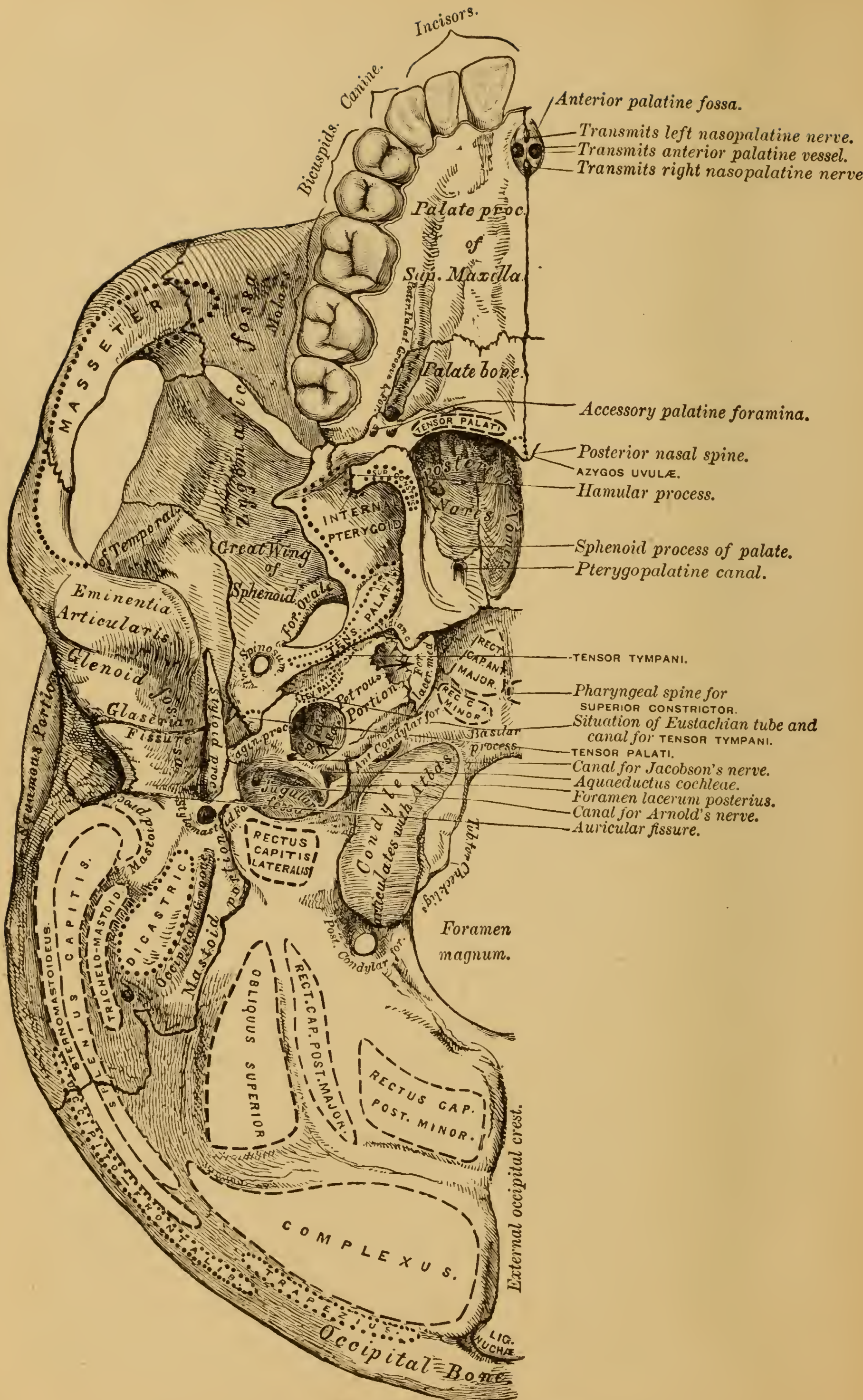


FIG. 23.—Base of the skull. External surface. (Gray.)

internal auditory meati for the passage of the auditory nerves and arteries and the facial nerves.

The Base of the Skull.—The *cerebral surface of the base* has just been described under the heading of the Inferior Surface of the Cranium. (Fig. 22.)

The *external or inferior surface of the base* (Fig. 23) (the mandible removed) presents the following points for study: (*a*) In front is the hard palate bordered by the teeth. Behind the incisor teeth is a depression in the palate known as the *anterior palatine fossa.* In the floor of this fossa are four foramina for the passage of nerves and blood-vessels to and from the nose. On the hard palate opposite the last molar teeth are the *posterior palatine foramina* transmitting arteries to the hard palate. (*b*) Behind the hard palate are seen the posterior openings of the nasal cavities on the outer sides of which are the two pterygoid processes of the sphenoid bone. (*c*) External to these processes are the *zygomatic fossæ* which contain three of the large muscles of mastication, the inferior maxillary division of the fifth nerve and the internal maxillary artery. These fossæ communicate with the orbits by means of the large *sphenomaxillary fissures.* (*d*) Numerous foramina the most important of which are: ovale, external opening of the carotid canal, posterior lacerated, condyloid and magnum. (*e*) Two pairs of articulating surfaces, the one to receive the condyles of the mandible and named the *glenoid fossæ,* the other to articulate with the first vertebra. (*f*) The styloid and mastoid processes which form pronounced landmarks and serve for the attachment of muscles.

The Lateral Aspect of the Skull.—The following landmarks present themselves for study. (*a*) The malar bone that forms the prominence of the cheek. (*b*) The zygoma which lies very superficially and affords attachment to the masseter muscle. (*c*) The external auditory meatus and (*d*) the styloid and mastoid processes. It is of interest to note that practically all of the bone that enters into the formation of the side of the skull above the zygoma is covered by the largest of the muscles of mastication, *i. e.,* the temporal.

The Anterior Aspect of the Skull or Face.—The anterior portion of the skull is termed the face. Fourteen bones enter into its make-up. Passing from above downward the following points of interest are noted: (*a*) The supra-orbital foramina or notches through which pass an artery and nerve bearing the same name. (*b*) The orbits, in which well-protected cavities lie the eyes. (*c*) The nasal fossæ. (*d*) The infra-orbital foramina which transmit the infra-orbital arteries and the end-branches of the superior maxillary nerves. (*e*) The prominent malar bones. (*f*) The teeth of the upper and lower jaws supported by their alveolar processes. (*g*) The mental foramina through each of which an artery and nerve of the same name emerge. (*h*) The mandible or lower jaw.

The Orbits.—These are irregular, conical cavities, with the base toward the exterior and the apex inward. The outer edge of the base is in the form of a strong bony ridge which projects a little beyond the eye and thus protects it from injury. Seven bones enter into the formation of the walls of the orbits. On the superior aspect of the outer wall near the base is a depression for the *lachrymal gland.* The orbit is in communication with various other cavities and fossæ by means of the following openings: (*a*) The optic foramen and (*b*) sphenoidal fissure open into the middle fossa; (*c*) the sphenomaxillary fissure into the sphenomaxillary and zygomatic fossæ; (*d*) on the inner wall, the anterior and posterior ethmoidal foramina, which transmit vessels of the same names and the former also the nasal nerve, lead into the anterior fossa; and (*e*) the nasal duct opens into the nose. The posterior opening of the infra-orbital canal is seen on the floor of the orbital cavity.

The Nasal Fossæ.—These are large, irregular shaped cavities extending from the floor of the cranium to the roof of the mouth. They are separated from each other by a thin partition made up of bones and cartilage and called the *nasal septum.*

In front these fossæ communicate with the exterior by means of two large openings called the *anterior nares.* In back they open into the pharynx through the *posterior nares or choanæ.*

The lateral walls are very irregular and are divided by shelf-like bones named turbinates (scroll-like) into three or more sections called *meati.* The turbinate bones are normally three in number and according to their position receive the names of inferior, middle and superior.

The floor of the nose is formed by the same bones that make up the hard palate, *i. e.*, the palatal process of the superior maxillary and the horizontal process of the palate bones. The superior surface of these processes receives the name, "floor of the nose," while the inferior surface is called the "roof of the mouth."

The nasal fossæ are in communication by means of openings and canals with the following cavities: (*a*) the cranium, (*b*) the orbits, (*c*) the pharynx, (*d*) the mouth, (*e*) three sinuses, *i. e.*, maxillary, frontal and sphenoidal, and (*f*) three sets of air cells, *i. e.*, anterior, middle and posterior ethmoidal.

According to function the nasal fossæ are divided into two parts, the olfactory and respiratory. The olfactory area is in the upper portion and extends down to include the middle turbinate bones on the one side and two-thirds of the septum on the other. The respiratory portion takes in the remainder of the cavity.

The nose is lined with mucous membrane which in the olfactory portion is non-ciliated but contains cells that are specialized to receive the sensations productive of smell. That in the respiratory portion is much thicker, contains large plexuses of veins and its cells are of the ciliated variety.

The *blood supply* to the nasal cavity comes through the internal maxillary, the ophthalmic and the facial arteries.

The *nerve supply* is of two kinds: (*a*) that of special sense through the first cranial or olfactory nerve and (*b*) that of common sensation through the fifth cranial or trifacial nerve.

The Bony Sinuses and Air Cells.—In all of the bones of the skull that have any great thickness we find cavities. The largest of these cavities are called sinuses while the smaller ones are called air cells. Their function is to reduce the weight of the bone and in the region of the mouth and nose to render the bone more resonant for the purpose of speech. The most important of these sinuses and air cells are the following:

Maxillary or Antra of Highmore.
Sphenoidal.
Frontal.
Anterior, Middle and Posterior Ethmoidal.
Mastoid.

The Maxillary Sinuses or Antra of Highmore.—These are two in number, situated within the bodies of the superior maxillary bones, external to the nose and below the orbits. In shape they are somewhat pyramidal, with their bases directed toward the nose and the apices at the prominence of the cheek. They open into the nasal chamber and are lined with mucous membrane which is directly continuous with that of the nose. Often the roots of the molar and bicuspid teeth form elevations on the floors of the sinuses and when diseased frequently infect the mucous membrane with most serious results.

The Sphenoidal Sinus.—One or two in number situated within the body of the sphenoid bone at the posterior aspect of the roof of the nose.

The Frontal Sinuses.—These are two fairly large cavities within the frontal bone. They are located immediately above the orbits and their position is marked approximately by the eyebrows. They are really a continuation of the anterior ethmoidal air cells of their respective sides and open by way of these cells into the nasal chamber. Congestion of these sinuses is a usual sequence in a so-called "cold in the head," and gives rise to the accompanying headache so frequently noted in this condition.

The Ethmoidal Air Cells.—There are three sets of these found within the lateral masses of the ethmoid bone and named according to their position, anterior, middle and posterior. They are lined with mucous membrane which is a continuation of that lining the nasal passages into which each set of cells open. These cells are often interconnected and frequently the posterior set communicates with the sphenoidal sinus.

The orifices of the canals that lead from the nose to the anterior ethmoidal cells are intimately associated with the openings into the antra. Thus it is that the antrum, the anterior ethmoidal cells and the frontal sinus of each side are made intercommunicating and their mucous membrane linings practically continuous with each other.

These anatomical facts make it very possible for an infection arising within one cavity to travel to one or both of the others. Cases are not uncommon in which an abscess on the root of an upper molar or bicuspid tooth infects the mucous membrane of the antrum and the discharge from this tissue passing into the nose infects the lining membrane of the canal that leads to the anterior ethmoidal air cells. The infection traveling up this canal will eventually involve these cells and then pass on to the frontal sinus, which, as has been before noted, is a direct continuation of the anterior ethmoidal cells.

The mastoid air cells or antra are situated within the mastoid portion of the temporal bones and will be mentioned under the description of the ear.

THE EYES.

These are the organs of vision and consist of two globular bodies situated within the orbits. They are freely movable by means of a ball-and-socket joint formed between the eyeball and a tough, fibrous membrane arranged in the form of a socket. This membrane receives the name of the *capsule of Tenon*. Movement of the eyeball is performed through the agency of six muscles that arise from the bony wall of the orbit and are attached to the ball at various points.

The anterior portion of the eye is covered with a modified mucous membrane which is reflected onto the lids and lines the inner side of these. This membrane is called the *conjunctiva* and covers that portion of the eye that is commonly called the "white."

The eyeball (Fig. 24) is made up of three coats within which are three refracting media. The *coats* are named:

1. Outer or fibrous.
2. Middle or vascular.
3. Inner or nervous.

The *refracting media* are:

1. Aqueous humor.
2. Crystalline lens.
3. Vitreous humor.

The Coats of the Eye.—*Fibrous Coat.*—This is divided into two parts: (*a*) Cornea, forming the anterior sixth of the sphere and (*b*) the sclera, forming the remainder. (*a*) The Cornea. This tissue is made up of cells that will transmit the rays of light and so may be likened to a window. It is more highly convex than the rest of the eyeball, giving this portion of the ball a bulging appearance. Its posterior edge is continued into the sclera. (*b*) The Sclera. This is a firm, inelastic, fibrous membrane forming the posterior five-sixths of the eyeball.

Vascular Coat.—This is divided into three parts:

The iris.
The ciliary body.
The choroid.

(*a*) The *iris* may be likened unto a circular curtain attached at the periphery and perforated in the center. This "hole" in the center is called the *pupil.* The iris contains pigment of varying tint and is the tissue that gives the color to the eye. In structure it consists for the most part of muscular fibers of two kinds, circular and radiating. When the circular contract the pupil becomes smaller and when the radiating are active the pupil enlarges.

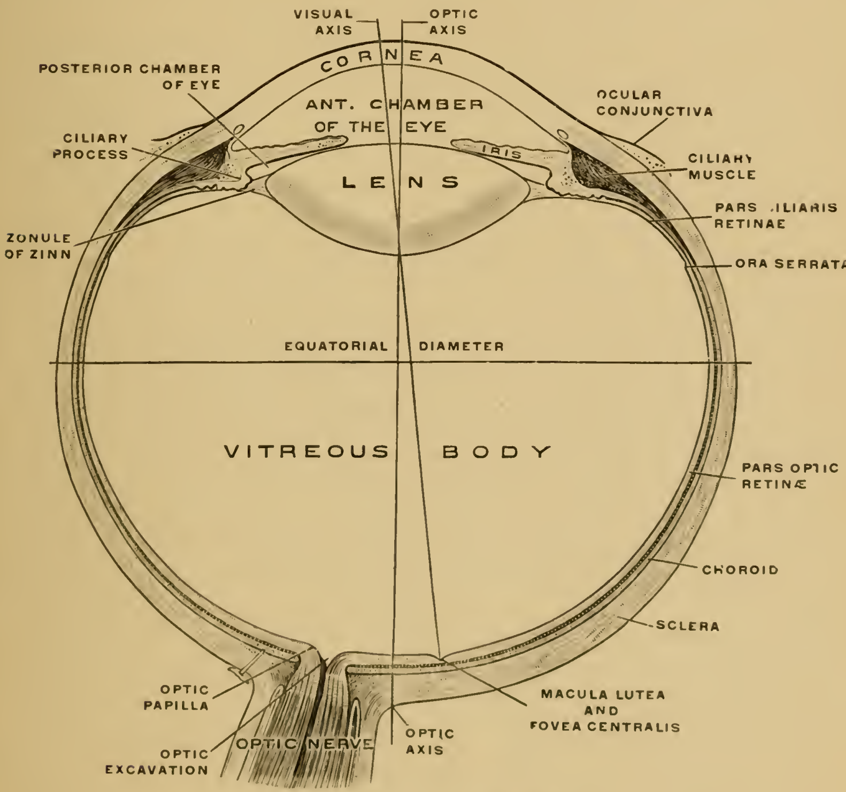


Fig. 24.—The right eye in horizontal section. (Toldt.)

The iris is suspended in a cavity formed by the cornea in front and the lens behind. It is nearly in contact with the latter structure. This cavity is known as the anterior chamber of the eye and is filled with a modified lymph called the *aqueous humor.*

(*b*) The *ciliary body* is made up of the ciliary processes and the ciliary muscle. The *ciliary processes* are composed of foldings, as it were, of the tissues making up the middle coat and are continuous at their posterior ends with the choroid and at their anterior ends with the suspensory ligament of the lens and the iris. They vary from sixty to eighty in number. The *ciliary muscle* is arranged in the form of a circular band of involuntary muscle fibers lying on the outer surface of the middle coat of the eye between the iris and the choroid. Its function is to control the convexity of the lens so that the rays of light may be properly focussed. The ciliary body is an exceedingly vascular area and consequently is very liable to be the seat of an infection, hence it has been designated as the "danger area" of the eye.

(*c*) The *choroid* is that portion of the middle coat that lies posterior to the ciliary body. It is made up of areolar tissue, bloodvessels, and considerable pigment.

Nervous Coat.—This is commonly called the *retina.* It is continuous with the optic nerve behind and extends forward about as far as the ciliary body where it ends in a jagged margin. It may be called the end-organ of the optic nerve with the special sense of vision as its function.

The fibers of the optic nerve are distributed to all parts of this membrane and end in physiological relationship with special cells, *the rods and cones,* of the neuro-epithelium lining the retina. The rods and cones receive the visual impressions and transfer them to the nerve fibers.

In examining the retina a white circular area is noted at the point of entrance of the optic nerve. This is called the *optic disc* and is the one point on the membrane where the rays of light will make no impression. In other words, it is a blind spot. For this reason it is located eccentrically so that the same rays of light will not be received on a blind spot in each eye, damaging the field of vision. Its position is somewhat to the inner side of the center. Directly in the center of the retina is the area where the most acute vision is to be had. This is called the *macula lutea* (yellow spot) because of its color.

The Interior of the Eyeball.—The interior of the eyeball is divided into two compartments by the lens. These are known as the *anterior* and *posterior chambers* of the eye. The anterior chamber is subdivided by the iris into two compartments which communicate with each other through the pupil.

The Refracting Media.—The Aqueous Humor.—This is a watery fluid filling the anterior chambers of the eye. It is derived from the vessels within the ciliary body and any excess is carried off through spaces and canals that empty into the ciliary veins.

The Crystalline Lens.—This is a biconvex, circular body made up of transparent fibrous tissue the component parts of which are cemented together with a transparent cement substance and the entire mass of tissue is surrounded by a capsule. It lies in a depression on the anterior surface of the vitreous body and is held in position by the *suspensory ligament of the lens.* The function of the lens is to bring the rays of light to a proper focus upon the retina.

The Vitreous Humor or Body.—In contact with the retina and filling the interior of the eyeball behind the lens is the vitreous humor. It is composed of a soft, jelly-like substance, perfectly transparent, and made up of semisolid connective tissue. This is surrounded by a membrane which is thickened anteriorly to form the *suspensory ligament of the lens* which holds the lens in position and affords attachment to the ciliary processes. The anterior surface of the vitreous body presents a cup-like depression into which the lens fits.

The Lachrymal Apparatus.—This consists of (*a*) the *lachrymal* or *tear gland* which is situated in a depression at the outer angle of the orbit at its upper aspect and from which several ducts lead and open through the conjunctiva of the upper lid just before this is reflected onto the eyeball; (*b*) the *lachrymal sac*, placed at the inner angle of the orbit and gathering in the tears by means of two small canals leading from the inner corner of each lid; and (*c*) the *nasal duct*, a passage that leads from the sac to the inferior meatus of the nose and discharges its contents into this cavity.

THE EARS.

The organ of hearing (Fig. 25) is divided into three portions:

1. The external ear.
2. The middle ear.
3. The internal ear or labyrinth.

The External Ear.—This consists of the cartilaginous structure that is commonly called the "ear" and the external portion of the auditory canal. The latter, known as the *external auditory canal*, is about one inch in length and runs inward and somewhat forward. It is separated from the middle ear by the tympanic membrane or drum. Its external opening is termed the *external auditory meatus*.

The Middle Ear.—This extends from the drum to the internal ear. It approximates one-sixth of an inch in length and is nearly one-half inch in its verticle diameter. In this cavity are the three ear bones or ossicles, as they are called. The middle ear is in communication with the mastoid antrum through a small opening and with the nasopharynx *via* the Eustachian tube.

The Tympanic Membrane or Drum.—This consists of an oval membrane, obliquely attached to the sides of the auditory canal, the upper portion being nearer the external opening. It presents a concave surface to the exterior. Between its layers is bound the "handle" of the malleus, one of the ossicles.

The Ear Ossicles.—These are three in number and are named from without inward, the malleus or hammer, the incus or anvil and the stapes or stirrup. (*a*) The malleus is bound to the drum by means of its handle while its so-called head articulates with the body of the incus. (*b*) The incus is shaped very much like a bicuspid tooth in that it has two root-like processes projecting from a body. The body articulates with the malleus and the longer of the processes with the stapes. (*c*) The stapes on the one hand articulates with the incus and on the other fits into the oval window located on the wall of the internal ear. These bones are held in position by ligaments that are attached to the wall of the middle ear. The *function* of the ear ossicles is to transmit and magnify the sound waves received by the tympanic membrane, conveying them to the lymph contained within the internal ear.

The Mastoid Antrum.—This consists of a moderately large cavity and several smaller ones, situated within the mastoid portion of the temporal bone just behind the middle ear and in communication with it. These air cavities are often the seat of infection.

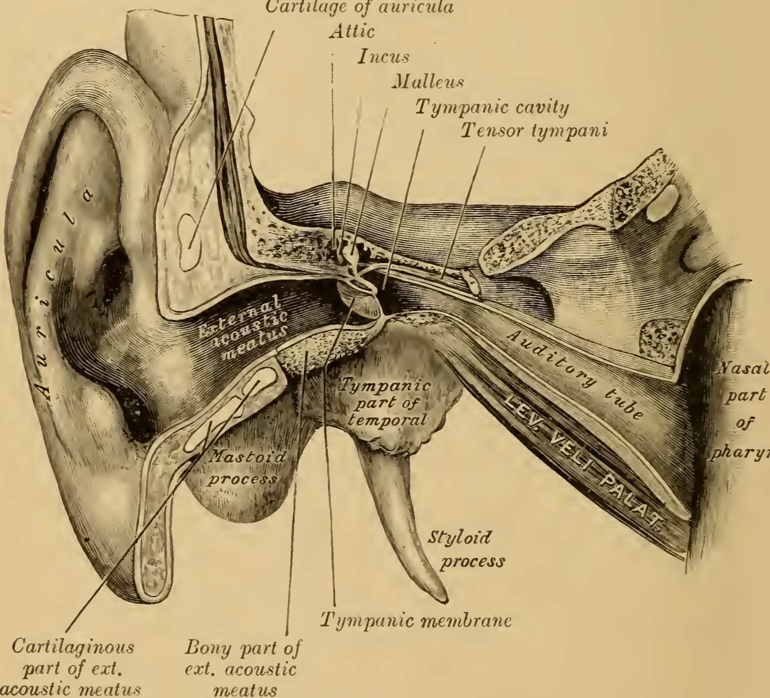


FIG. 25.—External and middle ear, opened from the front. Right side. (Gray.)

The Eustachean Tube.—This canal begins at the anterior end of the middle-ear cavity, passes downward, forward and somewhat inward to the nasopharynx. It is about an inch and a half in length. The *function* of the Eustachian tube is to keep the air within the middle ear of the same density as that of the exterior. This prevents any damage to the drum arising from inequality of air pressure.

The Internal Ear or Labyrinth (Fig. 26).—This consists of three parts:

The vestibule.
The cochlea.
The semicircular canals.

Each one of these parts is made up of bony walls enclosing within them a membraneous structure. Separating the membraneous portion from the bony is lymph which receives the name of *perilymph*, while within the membraneous structures is more lymph, termed *endolymph*.

Of the three parts of the internal ear, the cochlea is placed anteriorly and the semicircular canals posteriorly, while the vestibule lies between them and serves as a connecting chamber.

The Vestibule.—In the external wall of the vestibule is the oval window into which, as already stated, fits the base of the stapes. The vestibule opens into the cochlea by one opening and into the semicircular canals by five openings. It contains two membraneous, sac-like structures, the *utricle* and the *saccule*. These are filled with endolymph and are connected with the membranous portions of the

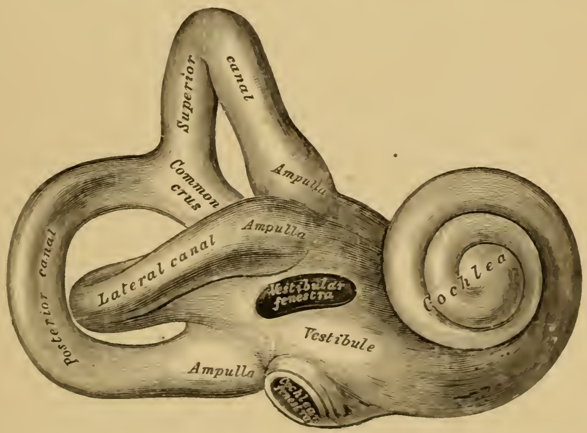


FIG. 26.—Right osseous labyrinth. Lateral view. (Gray.)

semicircular canals and cochlea. In the utricle are also found many minute calcareous bodies called *otoliths*. These, by shifting their positions under varying conditions, transmit impulses to the nerve filaments in the mucous membrane of the utricle.

The Cochlea.—This in structure resembles a snail's shell and from the exterior is somewhat cone-shaped. It is placed with the apex outward. In its base are found numerous openings through which the branches of the auditory nerve pass. The base measures about two-fifths of an inch in diameter and the height of the structure is approximately one-quarter of an inch. The spiral canal within the cochlea makes about two and a half turns around the central axis. This canal is divided into three compartments running the whole length of the spirals. In the median compartment, which is the membraneous portion of the cochlea, is the *organ of Corti*, the name given the structure which receives the sound waves and transmits them to the filaments of the auditory nerve ending within the mucous membrane lining. This compartment is filled with endolymph.

The Semicircular Canals.—These are three in number and come off from the posterior aspect of the vestibule. They are so located as to be at right angles with one another. Two are in the verticle plane and one in the horizontal. Within these are the membraneous semi-circular canals, external to which is the perilymph and within which is the endolymph. They are lined with a special form of epithelium, the cells of which are in intimate relationship with the end filaments of the vestibular branches of the auditory nerve. These canals undoubtedly play an important part in the mechanism concerned in the maintenance of the equilibrium of the body.

Interconnection of the Nerve Supply of the Ears and Teeth.—The nerves to the ears are associated, through certain of the cranial ganglia, with the nerves that supply the teeth. Hence it is not uncommon to have earache accompanied by toothache or *vice versa*. At times earache may be the only symptom of a dental lesion.

THE MOUTH.

The mouth may be defined as the cavity at the beginning of the alimentary canal. It is bounded in *front* by the lips; *laterally* by the cheeks; *above* by the hard and soft palates; and *below* by the mylo-hyoid muscle which forms its floor. It contains the teeth and the tongue. Anteriorly the mouth opens to the exterior through the lips and posteriorly into the pharynx through the *fauces*. The mouth cavity is divided into two portions: (*a*) the vestibule, which lies between the lips, cheeks and teeth, and (*b*) the mouth proper or oral cavity, internal to the teeth. It is lined with mucous membrane of the stratified squamous variety. This membrane contains many mucous glands which pour their contents into the mouth.

The bony framework of the mouth is formed by (*a*) the superior maxillary bones, (*b*) the palate bones, and (*c*) the inferior maxillary bone or mandible.

The Superior Maxillary Bones (Fig. 27).—These are two in number and form the bulk of bone below the forehead exclusive of the prominences of the cheeks. Each superior maxilla consists of a *body* and *four processes*.

The Body.—On the *anterior surface* is seen, from above downward: (*a*) a portion of the orbital margin; (*b*) the infra-orbital foramen; (*c*) incisive fossa, a depression above the roots of the incisor teeth; (*d*) the canine fossa, a depression behind the prominent root of the cuspid tooth, and (*e*) the ridges of bone overlying the roots of the incisor and cuspid teeth; (*f*) in the median line a sharp process of bone called the nasal spine.

The *superior surface* of the body forms a portion of the floor of the orbit. It presents the inner opening of the infra-orbital canal.

From this canal are given off branch canals which convey the bloodvessels and nerves to the anterior teeth and bicuspids.

The *posterior surface* forms part of the zygomatic fossa and presents the openings of canals that take the bloodvessels and nerves to the molar teeth.

The *internal or nasal surface* forms a portion of the outer wall of the nasal cavity. It presents the opening that leads into the maxillary sinus or antrum of Highmore. This large air cavity is situated within the body of the superior maxillary bone and has been described under the heading of Sinuses.

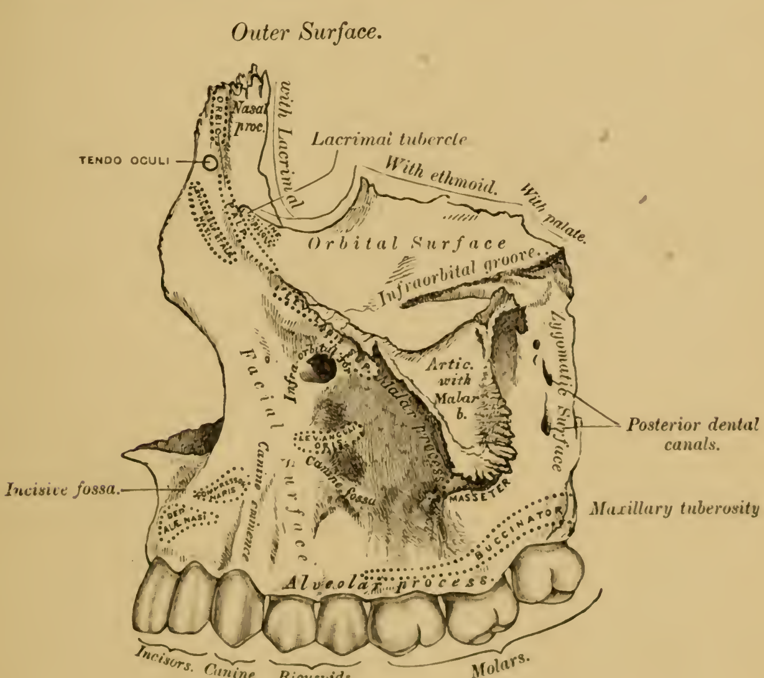


Fig. 27.—Left maxilla. Outer surface.

The Four Processes:

1. Nasal.
2. Malar.
3. Palate.
4. Alveolar.

The *nasal process* is situated between the nose and the orbit, projecting upward from the body of the bone.

The *malar process* manifests itself on the outer surface of the bone and articulates with the malar bone.

The *palate process* projects horizontally from the inner surface of the body, articulates with the corresponding process of the superior maxillary bone of the opposite side and thus forms with its superior surface the anterior portion of the floor of the nose and with its inferior surface, the corresponding portion of the roof of the mouth.

The *alveolar process* is built up on the lower, outer border of the body for the purpose of supporting the teeth, the roots of which are found within its substance.

The Palate Bones.—These are two in number. In form they may be likened to the letter "L." Their upright portion, called the verticle plate, helps to form the outer wall of the nasal cavity. The bone corresponding to the base of the "L" is called the horizontal plate and articulates anteriorly with the palate process of the superior maxilla, thus aiding in the formation of the floor of the nose and roof of the mouth. Posteriorly the horizontal plate ends in a free border to which is attached the soft palate.

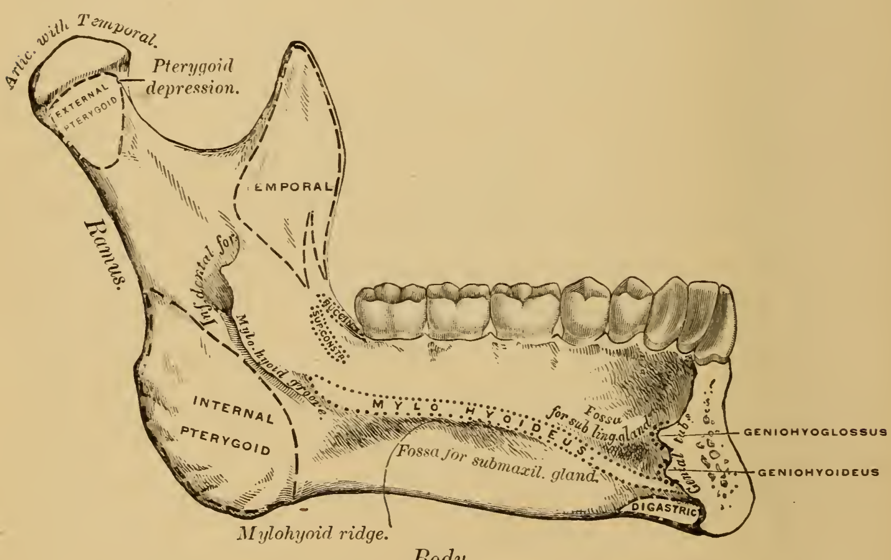


FIG. 28.—The mandible. Inner surface. Side view.

The Inferior Maxillary Bone or Mandible (Fig. 28).—In form this bone resembles a horseshoe and is composed of a *body* and two *rami*. The latter arise from the posterior ends of the body. The angle formed between the rami and the body varies in degree according to race, type and age. The mandible is the only bone in the skull that is movable.

The Body.—The *external surface* is usually concave from above downward, and ends below in a thick ridge. In the median line in front is another thick ridge placed at right angles to the border. This receives the name of *symphysis menti.* Below, this fuses with the lower border of the bone to form the prominence of the chin.

In the region of the first and second bicuspid teeth and about half-way between the upper and lower borders of the bone are seen the *mental foramina,* one on either side. These are the anterior openings of the mandibular canals and transmit the mental vessels and nerves. The *alveolar process* is built on the superior border of the body and serves to maintain the lower teeth in position.

The *internal surface* (Fig. 28) presents in the median line *four tubercles* for the attachment of muscles. Passing back from these along the body of the bone and half-way between its borders is a ridge called the *mylohyoid ridge.* This serves for the attachment of the muscle of the same name which forms the floor of the mouth. Above this ridge just to either side of the median line are two depressions called the *sublingual fossæ* and resting in these lie the *sublingual glands.* Below this ridge in the region of the bicuspid and molar teeth on either side, are two other depressions that receive the *submaxillary glands.* The sublingual and submaxillary glands pour their secretion into the mouth through a common duct, Wharton's, the opening of which is on either side of the frenum of the tongue.

The Rami.—The *external surface* of each ramus serves for the attachment of one of the muscles of mastication, the masseter. The *posterior border* terminates below in what is commonly called the angle of the jaw. The *internal surface* serves as a place of attachment for certain of the muscles of mastication, *i. e.*, the internal pterygoid and the temporal. This surface presents about at its midpoint an opening, the *inferior dental foramen,* which leads into the canal of the same name. It transmits the inferior dental artery and nerve which furnish the blood and nerve supply to the lower teeth.

The *superior border* of each ramus presents two prominences between which is a well-marked notch. The anterior prominence is called the *coronoid process* and serves for the attachment of the temporal muscle. The posterior prominence is surmounted with an articular cartilage, receives the name of the *condyle,* and enters into the formation of the temporomaxillary articulation.

The Temporomaxillary Articulation.—This is a sliding hinge joint and is formed by the glenoid fossa on the base of the skull and the condyle of the mandible. The glenoid fossa is somewhat cup-shaped and is limited anteriorly by a ridge, the *eminentia articularis.* This aids the ligaments of the joint in restricting the forward slide of the mandible. The articulating surface of the condyle is oblong with the long diameter in the transverse plane.

The Muscles Active in Moving the Mandible.—These may be divided into two sets: (*a*) the so-called "muscles of mastication" which bring the lower teeth in contact with the upper in the process of chewing by raising the mandible and (*b*) the depressor muscles or those which pull the mandible downward as in opening the mouth.

(*a*) The *muscles of mastication* are five in number, *i. e.*:
Temporal.
Masseter.
Buccinator.
Internal pterygoid.
External pterygoid.

(*b*) The depressor muscles are also five in number.

The Lips and the Cheeks.—These structures are made up of muscles and fibro-elastic tissue. They are covered on the external surface with skin and on their internal or oral surface with mucous membrane. These two coverings unite at the outer border of the lips. The mucous membrane contains many mucous glands which pour their secretion into the mouth cavity. In the center of the upper lip and sometimes of the lower a fold of mucous membrane is reflected onto the alveolar process. This is called the *frenum.*

On the inside of the cheek about opposite the upper second molar tooth is seen a small papilla which marks the opening of the duct leading from the parotid gland.

The Hard Palate.—The hard palate is formed by the palate processes of the superior maxillary bones and the horizontal processes of the palate bones. Posteriorly it ends in a free border to which the soft palate is attached. It is covered with mucous membrane the surface of which anteriorly is thrown into folds, called *rugæ.*

The Soft Palate.—This structure is attached to the posterior border of the hard palate and is formed by five different muscles. These are in turn covered with mucous membrane. The function of this structure is to shut off the nasal passage from the mouth during the act of swallowing.

The Tongue.—The tongue is a muscular organ composed of a *root, a body* and an anterior free extremity or *tip.* It is made up of five muscles and is covered with mucous membrane. The under surface is attached to the floor of the mouth by a fold of this membrane called the frenum. The base of the tongue is attached to the hyoid bone and to the muscles of the pharynx.

On the surface of the tongue are seen three varieties of *papillæ.* These are composed of a connective-tissue core developed in the corium (tissue under the epithelium) and covered with epithelium. The most important of these papillæ are situated on the back part of the tongue, are arranged in the form of a "V" with the point backward, are eight to twelve in number and are called *circumvallate papillæ.* At the base of these papillæ are located the *taste buds,* specialized bodies in which filaments of the glossopharyngeal nerve end and through which media the sense of taste is active.

On the base of the tongue, behind the circumvallate papillæ, is found considerable lymphoid tissue. This is given the name of the *lingual tonsil.*

The nerve supply of the tongue is interesting in that it is derived from three different sources. (*a*) The nerve of special sense has been mentioned above as the glossopharyngeal. (*b*) The nerve of common sensation is the fifth cranial or trifacial and (*c*) the motor nerve to the muscles of this organ is the hypoglossal or twelfth cranial.

The Nerve and Blood Supply of the Dental Tissues.—The *nerve supply* to the structures entering into the formation of and associated with the oral cavity is through the trifacial or fifth cranial nerves and the facial or seventh cranial nerves. Their *blood supply* is brought by the internal maxillary artery, a branch of the external carotid artery.

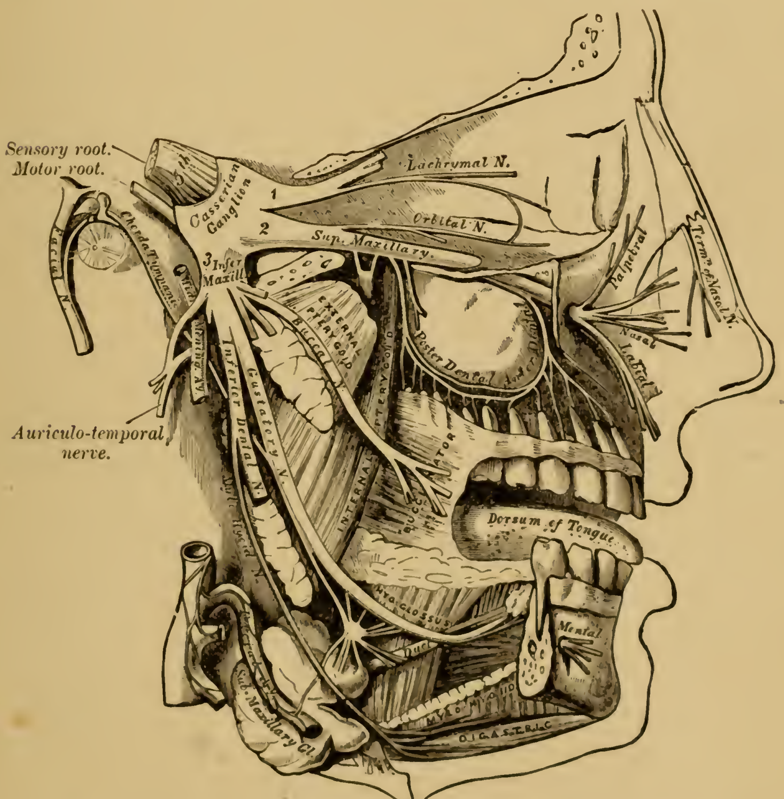


Fig. 29.—Distribution of the second and third divisions of the trigeminal nerve. (Gray.)

The Trifacial or Fifth Cranial Nerve (Fig. 29).—This is the great *sensory nerve* of the head and face. It also contains a few motor fibers. It leaves the pons Varolii (a portion of the spinal cord just below the brain) in the form of two roots, an anterior motor and a posterior sensory. The latter root enters a large ganglion, the Gasserian, situated on the floor of the middle fossa of the skull just behind the foramen ovale. From this ganglion three large trunks are given off as follows:

The ophthalmic or first division.
The superior maxillary or second division.
The inferior maxillary or third division.

The *ophthalmic division* passes forward and enters the orbit through the sphenoidal fissure supplying the various structures in this cavity, the nasal cavity and the upper part of the face, with sensation.

II. The *superior maxillary division* leaves the cranium through the foramen rotundum entering the sphenomaxillary fossa. From this fossa it gains entrance to the orbit *via* the sphenomaxillary fissure. It passes along the floor of the orbit to the infra-orbital canal which it enters and then emerges from the canal through the infra-orbital foramen to supply the tissues in the region of this opening. Just before this division enters the orbit it gives off branches that supply the upper molar teeth. These reach the teeth by passing through bony canals, the entrance to which are found on the posterior surface of the superior maxillary bones. While in the infra-orbital canal branches are given off that supply the upper bicuspid, cuspid and incisor teeth.

There are no motor fibers found in either the ophthalmic or superior maxillary divisions of this nerve. Their function is purely a sensory one, that of touch and pain, to those structures to which they are distributed.

The inferior maxillary division emerges from the cranium through the foramen ovale. Accompanying it through this opening is the motor root of the nerve which joins the sensory division just outside the cranium. This combined trunk is now located in the zygomatic fossa and almost immediately is found to divide again. One of these divisions contains nearly all of the motor fibers and is distributed to the muscles of mastication, excluding the buccinator. The other, containing but a few motor fibers and made up mostly of sensory ones, is the larger of the two and divides into three branches, *i. e.*, (*a*) the auriculotemporal, which supplies the tissues about the ear, the temporomandibular articulation and sends communicating branches to the facial (seventh cranial) nerve; (*b*) the lingual which, as previously stated, supplies common sensation to the tongue; and (*c*) the inferior dental nerve. This last branch enters the mandibular canal in the body of the inferior maxillary bone, traverses its entire length and emerges through the mental foramen as the mental nerve to supply sensation to the surrounding tissues. While in the mandibular canal minute branches are given off to the various lower teeth.

Just as the inferior dental nerve is about to enter the mandibular canal it gives off quite a large branch, the mylohyoid nerve. This contains motor fibers and passes downward to supply the mylohyoid and digastric muscles.

The Facial or Seventh Cranial Nerve.—This is the great *motor nerve* of the head and face. It supplies the muscles of expression, certain of the ear muscles, one of the muscles of mastication, the buccinator, and sends communicating branches to two important cranial ganglia.

The *facial nerve* emerges from the pons Varolii and enters the internal auditory meatus accompanying the auditory nerve and artery. It soon leaves the auditory canal and enters another bony canal known as the aqueductus Fallopii and comes out on the exterior of the skull through the stylomastoid foramen. It then enters the substance of the parotid gland and breaks up within this structure into a large terminal arborization known as the pes anserinus (duck's foot).

Within the aqueductus Fallopii several branches are given off, two of which go to cranial ganglia. After leaving the stylomastoid foramen branches are given off to muscles attached to the temporal bone near the styloid process and about the external auditory meatus. The branches forming the terminal arborization supply the muscles of expression situated about the eyes, nose, and the upper and lower lips. One of these branches also supplies the buccinator muscle.

The Internal Maxillary Artery.—This is one of the terminal branches of the external carotid artery and arises from that vessel at a point just below the condyle of the mandible. It embeds itself deeply in the substance of the parotid gland, passes internal to the ramus of the jaw, through the zygomatic fossa to the sphenomaxillary fossa. Here it breaks up into its terminal branches. One of these, the *infra-orbital*, is really a continuation of the main trunk and enters the orbit through the sphenomaxillary fissure, passes forward on the floor of the orbit in company with the superior maxillary division of the fifth nerve, enters the infra-orbital canal and emerges onto the face through the infra-orbital foramen. While in the infra-orbital canal it gives off branches that supply the upper bicuspid, cuspid and incisor teeth.

Important Branches of the Internal Maxillary Artery.—Soon after its origin from the external carotid, the internal maxillary artery gives off (*a*) the middle meningeal artery, that passes upward and enters the cranium, therein to supply the various bones entering into the formation of this structure and (*b*) the mandibular or inferior dental artery, that passes downward in company with the inferior maxillary division of the fifth nerve and enters the mandibular canal. It gives off branches to the lower teeth as it passes through the canal and then emerges onto the chin as the mental artery through the foramen of the same name. (*c*) Branches to the muscles in the maxillary region given off as the artery traverses the zygomatic fossa. (*d*) In the sphenomaxillary fossa small branches that enter the canals in the posterior portion of the superior maxillary bones and supply the upper molar teeth. (*e*) The infra-orbital artery which has been described in the preceding paragraph.

The Salivary Glands.—There are three pairs of these glandular structures, *i. e.*: (*a*) parotid; (*b*) the submaxillary; and (*c*) the sublingual.

The *parotid* (near the ear) *glands,* one on either side, are situated below and in front of the ears and extend from the zygoma, above, to the angle of the jaw, below. Their ducts, called Steno's or Stenson's, open into the mouth at points about opposite the upper second molar teeth.

The *submaxillary glands* are situated below the floor of the mouth, in contact with the inner surface of the mandible in the region of the bicuspid and molar teeth. The ducts from these glands join with the ducts from the sublingual glands and make their entrance into the mouth on either side of the frenum of the tongue. These ducts are known as Wharton's.

The *sublingual glands* are the smallest of the salivary glands and are situated above the floor of the mouth, in the sublingual fossæ of the mandible. As has been previously stated, their ducts join with those from the submaxillary glands and make their entrance into the mouth alongside of the frenum of the tongue.

The Fauces and the Tonsils.—The opening leading from the mouth to the pharynx is called the fauces. It is bounded above by the soft palate, below by the base of the tongue, and on either side by two pairs of muscles which receive the names of *anterior pillars* and *posterior pillars of the fauces.* Between these two pillars, on either side, lie the *faucial tonsils.* These are lymph nodes which probably act as filtering plants for the lymphatic vessels draining the mouth. Whatever other function they may have still remains a mystery.

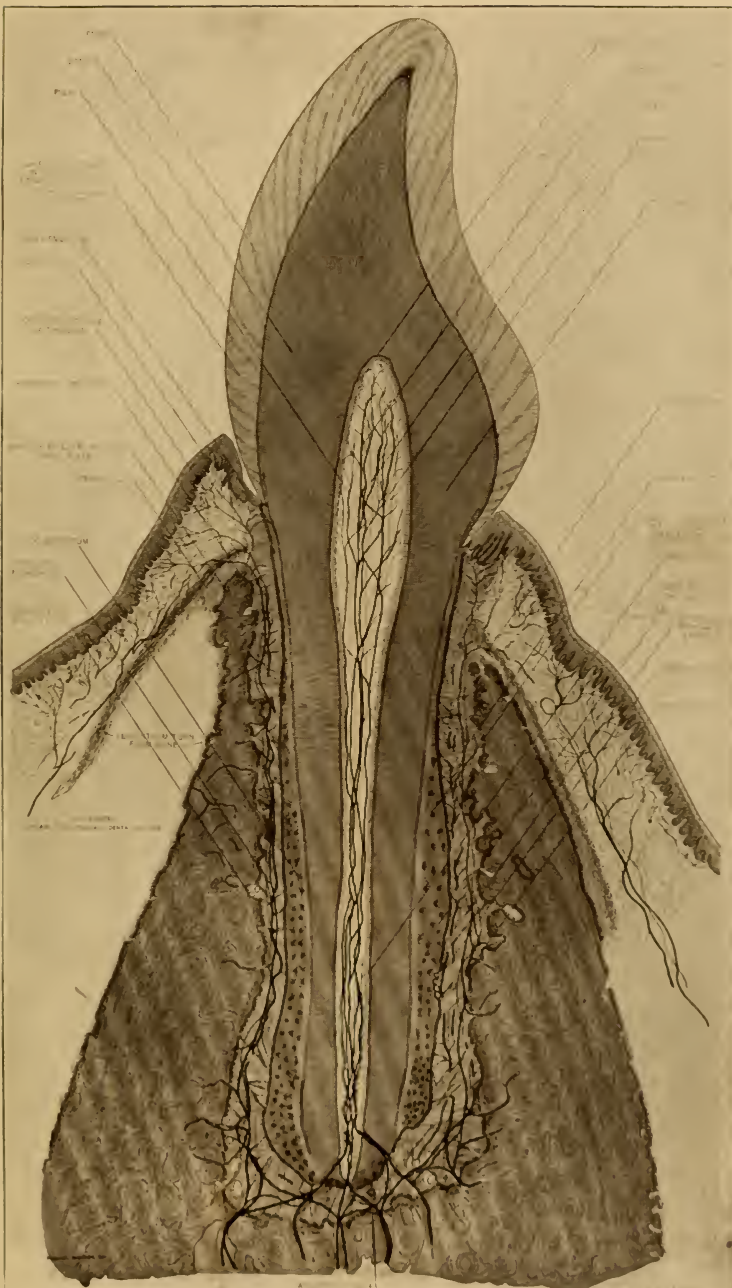
There are two other masses of lymphoid tissue in close relationship to the mouth. One has been mentioned under the description of the tongue. This is called the *lingual tonsil.* The other is known as the *pharyngeal tonsil* and is located on the posterior wall of the pharynx, just above the level of the soft palate and between the openings of the Eustachian tubes. Enlargement of the pharyngeal tonsil often occurs in children. The growth, commonly known as *adenoids,* so completely fills the upper portion of the pharynx as to shut off the passages into the nose and the child is forced to breathe through the mouth. Mouth-breathing, when continued for some time, produces very characteristic symptoms chief among which is a severe oral deformity. Blocking of the orifices of the Eustachian tubes by these growths often produces impairment of hearing.

THE TEETH.

The teeth may be defined as the calcified structures attached to the jaw-bones by the alveolar processes and having as their most important function the breaking up of food material in preparation for digestion.

The teeth must not be thought of as a part of the osseous system of the body for they are in no way related to such tissues morphologically. Their origin and structure will be discussed later under Development.

PLATE VII



A Diagram of a Section through an Incisor.

Showing the bloodvessels of the pulp and peridental membrane. The bone is represented as much too dense.

The teeth make their appearance in two series or sets. The first, known as the *deciduous* (falling off), *temporary or milk teeth,* are twenty in number, equally divided between each jaw, and named as follows:

Central incisors.
Lateral incisors.
Cuspids.
First molars.
Second molars.

The second series or set, known as the *permanent teeth,* number thirty-two when complete. The increase in the number is accounted for by the following: There are three molars on each side in the permanent set instead of two, as seen in the deciduous. Furthermore, these are all three erupted *behind* the deciduous molars. The latter are replaced when shed by teeth known as the bicuspids. It is therefore to be noted that while the molar teeth in the deciduous set lie in contact with the cuspids, the molar teeth of the permanent set are separated from their cuspids by two teeth, the bicuspids. The permanent teeth are therefore named as follows:

Central incisors.
Lateral incisors.
Cuspids.
First bicuspids.
Second bicuspids.
First molars.
Second molars.
Third molars.

Occlusion.—The teeth are arranged in two gracefully curving arches, the lower of which is somewhat the smaller so that the upper overlaps it. The teeth of one arch do not meet those of the other in an end-to-end arrangement, but are dovetailed, as it were, between each other. This brings broad surfaces in contact instead of mere points. There are over one hundred of these surfaces that are in contact when all the teeth are present and in their proper position. These surfaces are known as *inclined planes* and it is the sliding together of these various inclined planes in a scissors-like action that properly prepares the food for digestion.

The normal arrangement of the inclined planes of the teeth when the jaws are closed is known as *occlusion or normal occlusion* (Fig. 30). In this arrangement it will be noted that every tooth, with but six exceptions, is in contact with four other teeth, *i. e.*, one on either side of it and two in the opposing arch. The teeth excluded from this rule are the lower central incisors and lower third molars which are in contact with but three teeth, and the upper third molars, which are in contact with but two teeth.

The Anatomy of the Tooth (Plate VII).—A tooth is divided into two parts, the *crown* and the *root.* The crown is that portion that projects above the gum; the root is that portion that, under normal conditions, is surrounded by gum and alveolar process. The bulk of the tooth is made up of calcified connective tissue called *dentin*. The crown portion of the dentin is covered by the hardest tissue in the body, *i. e.*, the *enamel*. This is of epithelial or lining tissue origin. The root portion of the dentin is covered with a calcified connective tissue that more closely resembles bone than any of the other tooth tissues. It is called the *cementum*. It slightly overlaps the enamel at the gum margin.

FIG. 30.—Normal occlusion. (Turner.)

In the center of the dentin, extending the whole length of the root and more or less into the crown, is a cavity called the *pulp cavity*. This contains the remains of the organ that was active when the tooth was being formed and which during this process deposited the dentin. This organ is called the *pulp*.

The pulp cavity is divided into two parts, that in the crown, known as the *pulp chamber*, and that in the root known as the *root canal*. The root canal communicates with the exterior through a small opening at the end of the root. This opening is given the name of the *apical foramen*. Sometimes more than one apical foramen is found. Through this opening the bloodvessels and nerves pass to the pulp.

Surrounding the root and separating it from the bony wall of the socket is a fibrous membrane known as the *peridental membrane*. This has for its most important function the binding of the tooth to the surrounding bone. The bone that supports the teeth is known as the *alveolar process*. This is formed about the roots of the teeth as they erupt. When a tooth is removed from its process an opening is left that resembles in outline the shape of the root. This cavity or socket is called an *alveolus*.

Surmounting the alveolar process is a dense, fibrous connective tissue called the *gum*. This is covered with mucous membrane continuous with that of the rest of the mouth.

Nomenclature.

The *neck, cervix* or *gingival margin* is that part of the tooth where the enamel and cementum meet.

The *apex* is the end of the root.

The *occlusal* end or surface is the top of the crown, *i. e.*, that portion of the tooth used in mastication.

A *cusp* is a projection or tubercle on the surface of the crown.

The *proximal* or *approximal* surface is that surface that adjoins the next tooth. The most prominent point of this surface is called the *point of contact* or *angle* of the tooth.

The *mesial* surface is that approximal surface that is nearest the median line of the arch, *i. e.*, a line drawn between the central incisors.

The *distal* surface is that approximal surface that is farthest away from such a line.

The surface of the incisors and cuspids that presents toward the lips is called the *labial surface*. The corresponding surface on the bicuspids and molars, presenting toward the cheeks, is termed the *buccal* surface.

The surface of the upper teeth presenting toward the palate is called the *palatal surface*. The corresponding surface on the lower teeth presents toward the tongue and is called the *lingual* surface. The palatal surface of the upper teeth is also often called the lingual surface.

Descriptive Anatomy of the Various Teeth.—**The Incisors** (Fig. 31).—The *crowns* of these teeth are wedge-shaped with the sharp edge downward. They present four surfaces and an incisal or cutting edge for study.

Labial Surface.—This is convex and on the upper incisors is irregularly quadrilateral while on the lower it is more of a triangle in outline. There are usually two grooves running vertically through this surface, known as the *developmental grooves*. All the borders of this surface are more or less convex, that at the gingivus being markedly so. This margin also ends in a distinct ridge. The *mesio-incisal angle* is quite sharp while the *disto-incisal angle* is rounded.

Lingual or Palatal Surface.—This is irregularly triangle in outline with the base downward. The surface is concave and the margins are outlined with ridges. Sometimes in the center of the cervical ridge is a rudimentary cusp at the base of which is a depression or pit.

Mesial and Distal Surfaces.—In outline these resemble arrow heads and their general surface is convex. They present two concave margins, the lingual and gingival, and one convex, the labial.

Incisal Edge.—The plane of this surface is more or less at a right angle to the crown. It is of varying thickness and in newly erupted teeth presents three tubercles. These quickly wear off as the teeth are used.

FIG. 31.—Left upper central incisor. Labial surface. (Johnson.)

The *roots* are cone-shaped with the labiolingual diameter greater than the mesiodistal. In the lower teeth the roots are even more flattened mesiodistally than in the upper. The apex of the root often has a slight distal bend.

Each *pulp cavity* follows roughly in outline the shape of the tooth.

Individual Characteristics of the Incisors.—*Upper Central.* This is the largest of the incisors. Its root is shorter and thicker than that of the others. *Upper lateral.* The distal surface of the crown of this tooth is very convex so that the point of contact is quite prominent and the incisal edge, oblique. Its root is the longest of the incisor roots. *Lower Central.* This is the smallest of the incisors.

The Cuspids (Fig. 32).—The *crowns* of these teeth present for study four surfaces and an incisal edge that takes the form of a cusp.

Labial Surface.—This is very convex and is marked with two developmental grooves between which is a prominent ridge. It has five borders as follows: two approximal, two incisal and one cervical. The approximal and the cervical are convex, while the incisal are usually quite straight. The disto-incisal border is the longer of the two.

Lingual Surface.—This is similar in outline to the labial and also presents a vertical ridge running through the center. The cervical end of this ridge is frequently marked with a tubercle.

Fig. 32. — Right upper cuspid. Labial surface. (Johnson.)

Fig. 33.—Right upper second bicuspid. Mesial surface. (Johnson.)

The mesial and distal surfaces are similar in outline to the corresponding surfaces of the incisors but are of greater dimensions labiolingually.

The Incisal Edge.—This is in the form of two planes, a mesial and a distal. The distal is the longer of the two. At their point of union they are joined by the labial and lingual ridges of the surfaces of the same name, to form the *cusp*.

The *roots* are conical, flattened mesiodistally and sometimes even concave on these sides. A distal bend at the apex is quite common. The upper cuspid has the longest root of any tooth in the mouth.

Each *pulp cavity* has the same general outline as the tooth.

Distinguishing Points between the Upper and Lower Cuspids.—The crown of the lower cuspid is more delicate in shape and slightly longer than the upper. Its root is shorter and more flattened mesially and distally.

The Bicuspids (Fig. 33).—The *crowns* of these teeth are irregularly cuboidal in form and present five surfaces for study, *i. e.*, buccal, lingual, mesial, distal and occlusal.

The *buccal surface* is convex, is bounded by five borders, and closely resembles the corresponding surface of a cuspid but is somewhat shorter than this tooth in its verticle dimension.

The *lingual surface* has the same general characteristics as the buccal but is smaller in all its dimensions.

The *mesial surface* is irregularly quadrilateral and slightly convex. Its buccal and lingual borders are convex, the lingual being considerably the shorter of the two. The cervical and occlusal borders are concave. The occlusal border of the upper bicuspids is quite "V" shaped, the apex of the "V" being between the cusps.

The *distal surface* closely resembles the mesial but is much more convex.

Occlusal Surface.—In outline this surface is somewhat egg-shaped. It presents for study two cusps, a central groove and a mesial and distal border. The *cusps* are placed buccally and lingually, the buccal being the larger one. Each cusp has four inclines or inclined planes, as they are usually called. These are named from the surface toward which they slope, *i. e.*, mesial, distal, buccal and lingual. The *groove* runs mesiodistally and separates the cusps. The *mesial border* is nearly straight while the *distal border* is decidedly convex. Both of these borders are surmounted with ridges.

The Roots.—The upper first bicuspid has two roots. Of these the buccal is the larger. All the other bicuspids have but one root. The buccolingual dimension of the root is the greater. Its mesial and distal sides are concave. A distal curve to the apex of the root is common.

The Pulp Cavity.—The *pulp chamber* can be more readily outlined in the bicuspids than in the incisors or cuspids. Its form follows roughly that of the crown while the shape of the *pulp canal* corresponds to that of the root. The upper first bicuspids have two pulp canals, the other bicuspids usually have but one, although two may be found.

Individual Characteristics of the Bicuspids.—The *upper first* is the largest of the bicuspids. It has two roots and two root canals.

The *lower first* is the smallest of the bicuspids. Its lingual cusp is very rudimentary. Its root is broad mesiodistally on the buccal side and quite narrow on the lingual side.

The Upper Molars (Fig. 34).—The *crowns* of these teeth are irregularly cuboidal, presenting the same five surfaces for study as do the bicuspids. The crowns of the molars are smaller in diameter at the neck than at their occlusal border.

The *buccal surface* is generally convex and is divided vertically by a groove. Often in the center of this surface is a pit. When this is present the buccal groove usually terminates in it. The buccal surface has four borders. Of these the occlusal is the most striking in that it is marked with two cusps.

The *lingual surface* resembles the buccal very closely except that the mesial and distal margins converge more at the cervix as they are continued into one root instead of two as is the case with corresponding margins of the buccal surface.

The mesial surface at the occlusal third is convex while the gingival two-thirds is straight or concave.

Fig. 34.—Left upper first molar. Buccal surface. (Johnson.)

The *distal surface* is similar to the mesial, though perhaps in general a little more convex.

The *occlusal surface* is irregularly rhomboidal, the acute angles being the mesiobuccal and the distolingual. It presents *four cusps*, two of which are buccal, called the mesiobuccal and distobuccal cusps, and two lingual, called the mesiolingual and the distolingual cusps. The mesiolingual is the largest cusp. Running obliquely across the occlusal surface there is in succession a groove, a ridge, and a second groove. The *first groove* begins in the middle of the mesial margin, and passes distally and buccally across the occlusal surface to the interval between the two cusps where it is continued over onto the buccal surface as the buccal groove. The *ridge* runs from the mesiolingual cusp to the distobuccal cusp. The *second groove* begins between the two lingual cusps as a continuation of the lingual groove and runs distally and buccally to the center of the distal margin. Just mesial and distal to the center of the oblique ridge are *fossæ.*

The Roots.—These are three in number, two being placed buccally and one lingually. The lingual is the largest root and the distobuccal the smallest. The apices of the two buccal roots tend to converge toward each other.

The Pulp Cavity.—The outline of the *pulp chamber* resembles the form of the crown. On the floor of this chamber are three openings leading into the *three root canals.*

Individual Characteristics of the Upper Molars.—The *first molar* is the largest of the upper molars. It is often distinguished by the fact that it has a *fifth cusp* situated at the mesio-occlusal corner of the lingual surface. This is very small and rudimentary. The roots of the first molar are usually larger and diverge from one another to a greater degree than in the other upper molars.

The *second molar* is often quite flattened mesiodistally. It never has the fifth cusp. Frequently the buccal roots show a distal inclination.

The *third molar,* with the lower third molar, is the most variable tooth in the head. If typical it should present but three cusps, the distolingual being lost. It has no oblique ridge, but presents instead a central fossa. There may be three roots or there may be but one, and the root canals vary with the number and position of the roots.

The Lower First Molar (Fig. 35).—The *crown* of this tooth is also irregularly cuboidal, and presents five surfaces for study.

The *buccal surface* differs from the buccal surface of the upper molars in that it is longer mesiodistally and presents two grooves instead of one. Its occlusal border is surmounted by three cusps instead of two.

The *lingual, mesial* and *distal surfaces* all resemble the corresponding surfaces of the upper first molar.

The *Occlusal Surface.*—This differs considerably from the corresponding surface of the upper. It is trapezoidal in outline with the long side buccally and is marked with five cusps, five grooves and a central fossa. The *cusps* are arranged three buccally, named from mesial to distal, mesiobuccal, buccal and distobuccal; and two lingually, named mesiolingual and distolingual. The *grooves* radiate from the central fossa and are named mesial, buccal, distobuccal (between the buccal and distobuccal cusps), distal and lingual. The mesiobuccal cusp is the largest and the distobuccal the smallest.

The Roots.—These are two in number and are placed one mesially and the other distally and are known by these names. They present a distal inclination. The mesial root is the larger.

The *Pulp Cavity.*—The *pulp chamber* resembles in outline the crown. The *pulp canals* are frequently three in number there often being two in the large mesial root.

The Lower Second Molar.—This resembles the first lower molar but is a smaller tooth and has but four cusps, the distobuccal being absent. The cusp corresponding to the buccal cusp of the first molar receives the name of distobuccal in the second molar.

The *occlusal surface* presents a central fossa and four grooves radiating from it.

The *roots* are somewhat smaller and are situated close together. But two *root canals* is the usual order. The roots have a marked distal inclination.

Fig. 35.—Right lower first molar. Buccal surface. (Johnson.)

The Lower Third Molar.—This is extremely variable in form but when typical should resemble the second molar in miniature.

Descriptive Anatomy of the Deciduous Teeth.—The deciduous teeth resemble the permanent teeth in their general form but are of course much smaller. Their cusps are not as well defined and the form of the molars and cuspids is such that they are larger at the neck than at the occlusal border.

The *incisors* and *cuspids* are very much like the corresponding teeth in the permanent denture; the *lower first molars* quite closely resemble the lower second permanent molars; the *second molars*, both upper and lower, are similar in design to the upper and lower first permanent molars; the *upper first* molars, however, are different in certain respects from any of the other teeth and therefore require a more detailed description.

The Upper First Deciduous Molar.—The *occlusal surface* presents three cusps, two buccally and one lingually. The latter is so large, however, that it makes this side about as long mesiodistally as the buccal. This surface presents a central fossa with three grooves radiating from it, *i. e.*, a mesial, a buccal and a distal.

The *buccal surface* resembles that of any upper molar; the *lingual* is very convex and has no groove; the *mesial* and *distal* are convex at their cervical borders.

Approximate Age at which the Various Teeth Erupt.—Lower teeth erupt before the upper as a rule.

The Deciduous Denture.

Central incisors, 6th to 8th month.
Lateral incisors, 8th to 10th month.
First molars, 10th to 16th month.
Cuspids, 16th to 20th month.
Second molars, 20th to 30th month.

The Permanent Denture.

First molars, 5th to 7th year.
Central incisors, 6th to 8th year.
Lateral incisors, 7th to 9th year.
First bicuspids, 8th to 10th year.
Lower cuspids, 9th to 11th year.
Second bicuspids, 10th to 12th year.
Upper cuspids, 11th to 13th year.
Second molars, 12th to 14th year.
Third molars, 17th year to any time later.

HISTOLOGY OF THE TEETH AND ASSOCIATED STRUCTURES.[1]

The Enamel.—This is the only calcified tissue in the body that is derived from epithelial structures. All others have their origin in connective tissue. Enamel is also the hardest of the tissues and contains no organic matter. Chemically it is made up for the most part of phosphate and carbonate of lime. As there is no organic matter to be found in its make-up it must be designated as a dead tissue. The epithelial cells that are active in its formation are destroyed when their work is finished.

Enamel is composed of two structural elements: (*a*) Enamel prisms or rods, and (*b*) a cementing substance.

The Enamel Rod (Fig. 36).—These are prismatic in form, having five or six sides and their average diameter is about one-half that of a red blood corpuscle. Throughout their entire length we find them alternately constricted and expanded. When placed side by side

[1] A resumé from Dental Histology and Embryology by Dr. F. B. Noyes.

these expansions and constrictions are not dovetailed into each other, but are arranged opposite one another.

The Cementing Substance.—Between the rods and filling up the spaces made by this peculiar arrangement of the prisms, is the cementing substance. This cementing substance is also highly calcified but is more susceptible to injury than the prisms. When enamel cracks the line of cleavage runs through the cementing substance and not across the rods. When an acid is brought in contact with the enamel the cementing substance is destroyed before the rods.

The enamel is formed from within outward so that on the surface of the tooth is the last enamel that is laid down. The prisms extend from the dentin outward and are arranged in a manner that will

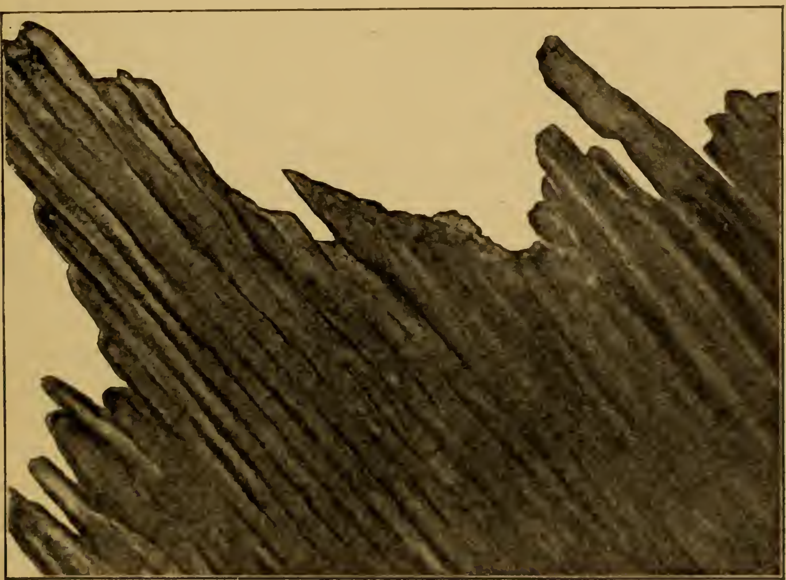


FIG. 36.—Enamel rods in thin etched section. (About 800 ×.) (Noyes.)

best resist the force that is brought upon them as the teeth are used. The prisms do not always run in a straight line from the dentin to the surface but in many places, especially where the stress is great, such as on the cusps of the teeth, they are intertwined with one another something like the strands of a rope. Such enamel is called *gnarled enamel*. *Straight enamel* is that in which the prisms run in practically a straight line from the dentin to the surface.

In sections of enamel two kinds of markings are distinguished on the cut surface: (*a*) striation and (*b*) stratification. The *striation* is quite like that of voluntary muscle fibers and is due to the alternating expansion and contraction segments of the rods. The *stratification* is seen in longitudinal sections only. It consists of dark bands running through the enamel. These are due to pigment being deposited in the enamel as it is formed. A portion of the enamel having been formed, upon the surface of this is deposited pigment. Following this another layer of enamel is laid down upon which is deposited more pigment, etc. These lines of stratification are therefore an index as to just how the enamel is laid down and show that the first layer is deposited at the occlusal end of the crown and successive layers work their way rootward.

When a tooth first erupts it is covered with a thin membrane called *Nasmyth's membrane.* This is the remains of the enamel organ, active during the formation of this tissue. It soon wears off as the tooth is brought into use.

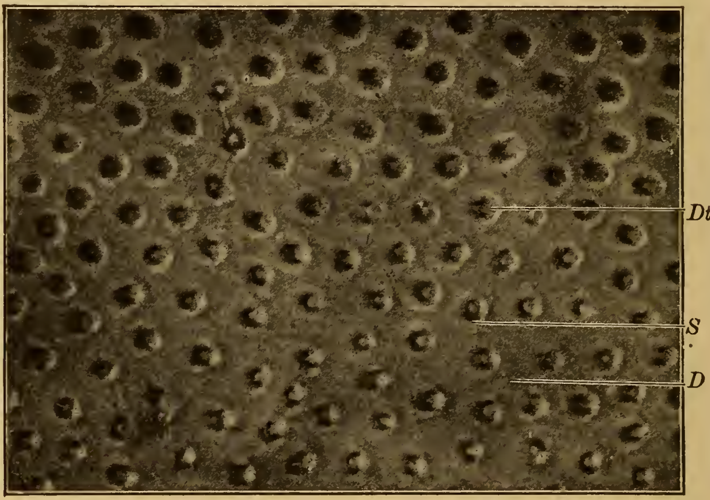


FIG. 37.—Dentin showing tubules in cross-section: *Dt*, dentinal tubules; *D*, dentin matrix; *S*, shadow of sheaths of Newman. (About 1150 ×.) (Noyes.)

Functions of the Enamel.—(*a*) It covers the exposed portion of the tooth and prevents irritation of the underlying sensative dentin. (*b*) By its hardness it resists abrasion from the force of mastication. Enamel *differs* from any other calcified tissue in the following details:

(*a*) It is formed by epithelial cells.

(*b*) It contains no organic material either in the form of cells or intercellular substance.

(*c*) The organ that forms it disappears after its work is complete.

(*d*) It is made of prisms cemented together. All other calcified tissue has fibrous connective tissue as its structural basis.

The Dentin (Fig. 37).—Dentin is a calcified connective tissue and is used to make up the bulk of the tooth. It contains considerable *organic* matter and yields gelatin when boiled. Its *inorganic matter* is mostly carbonate and phosphate of lime.

Structurally dentin is made up of the following elements:

(*a*) Dentin matrix.

(*b*) The dentinal tubules with their walls which latter structures are known under the name of the "sheaths of Neuman."

(*c*) The dentinal fibrils.

The Dentin Matrix.—This is a homogeneous material that is very elastic. As seen with the unaided eye it is yellowish. It is composed of about one-third organic material and two-thirds inorganic in the form of lime salts.

The Dentinal Tubules.—Extending throughout the matrix and radiating from the pulp cavity are minute tubes. These take a spiral course in their passage through the matrix. They also intercommunicate with one another. They end at the dento-enamel or dento-cemental junction. At the former junction they branch close to their termination in delta-like formations. These deltas are in communication with one another. This intimate interconnection of many tubules explains why the dento-enamel junction is such a sensitive area under the action of instruments. At the dentocemental junction the tubules open into spaces lying between the cement and the dentin. These spaces, ranging as they do along the whole length of the root, form what is known as the "*granular layer of Tomes.*" (Fig. 38.)

The matrix immediately surrounding the tubules is of a more dense composition than that in other parts. This densely formed portion receives the name of the *sheath of Neuman.* The name is somewhat misleading for it is not a true membrane, but is undoubtedly a specialized portion of the matrix itself forming a wall, as it were, to the tubes. It has been found that the sheaths of Neuman have considerable elastin as one of their component elements.

The Dentinal Fibrils.—These are the protoplasmic processes found in the tubules and are extensions from the cells of the pulp that were active in the formation of the dentin. These cells are called *odontoblasts.*

Function of the Dentin.—(*a*) Forms the great bulk of the tooth.

(*b*) Acts as an elastic cushion to the enamel so that this tissue will not break under stress.

(*c*) Gives strength to the whole tooth.

The Cementum (Fig. 38).—This is also a calcified connective tissue. It more nearly resembles bone than does the dentin. It is arranged in consecutive layers around the tooth root and slightly overlaps the enamel at the cervical margin.

Structurally cementum is made up of the following elements:

(*a*) The lamellæ.

(*b*) The lacunæ from which radiate the canaliculi.

(*c*) Cement cells or corpuscles.

(*d*) The embedded fibers of the peridental membrane.

The Lamellæ.—This is the name given to the layers of cementum. These vary in thickness according to the position on the root, being thinest at the gingival margin and thickest at the apex. They are arranged concentrically about the root. There is a continuous formation of cementum going on throughout life so that the older the individual, the more layers of cementum there will be. By virtue of this property of continuous formation the cementum is the one tissue of the tooth that is capable of repairing itself after injury. Destruction of the dentin on the surface of the root may also be repaired by the cement cells filling in such areas with cementum.

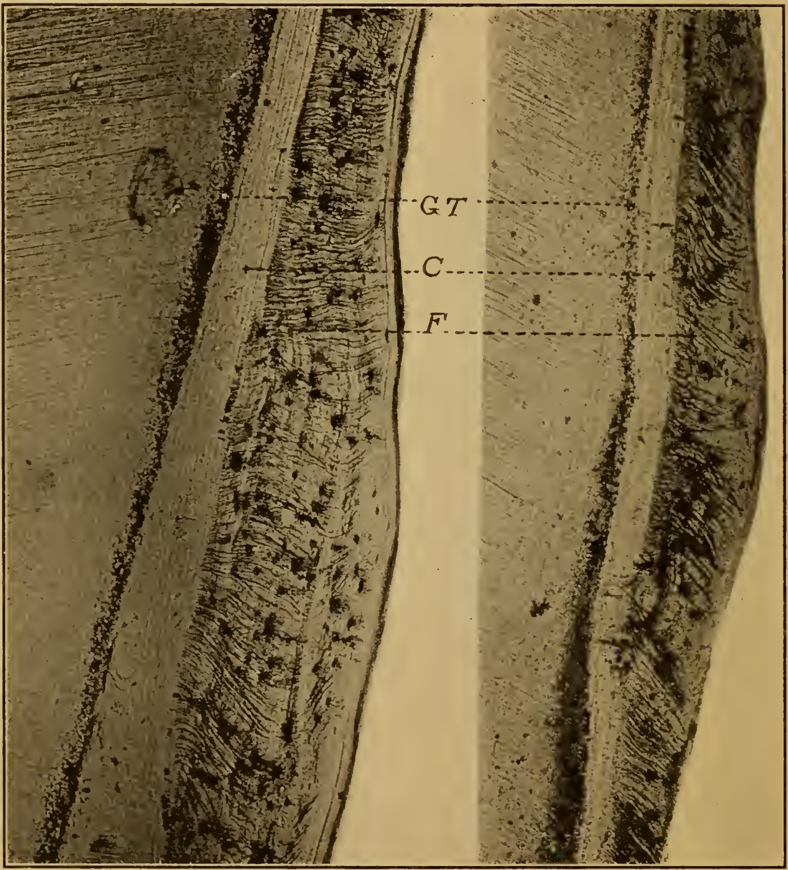


FIG. 38.—Two fields of cementum showing penetrating fibers: *GT*, granular layer of Tomes; *C*, cementum not showing fibers; *F*, penetrating fibers. (About 54 ×.) (Noyes.)

The Lacunæ.—The lacunæ are minute spaces scattered throughout the cementum, being both in the substance of the lamellæ and between the various layers. From these radiate in all directions minute canals called *canaliculi.* These canaliculi intercommunicate with those from the adjacent lacunæ. The *cement cells or corpuscles* lie in the lacunæ. They are the cells that are active in the formation of cementum. Their protoplasmic processes extend into the canaliculi.

The Embedded Fibers of the Peridental Membrane.—The cement cells previous to the formation of cementum are located in the membrane that surrounds the root, *the peridental membrane.* The cement is built from within outward, *i. e.*, that nearest the dentin is the first to be formed. As these cells, called *cementoblasts* when active, form the various lamellæ they build themselves into the structure that they are forming. In this process many of the fibers of the peridental membrane are also built into the cementum and after a time become more or less calcified. These constitute the embedded fibers.

On the opposite side of the peridental membrane, *i. e.*, that side that is in relationship to the bone of the alveolus, we find that fibers of the membrane are similarly built into the bone. Through the agency of all these embedded fibers the tooth is firmly held in its socket.

The Function of the Cementum.—It is the tissue which through its ability to attach the tooth to the surrounding connective tissue, holds it in position. The cementum may therefore be considered as the most important of the *tooth* tissues.

The Pulp.—This is the structure occupying the cavity within the dentin. It represents the remains of the organ that was active when the dentin was formed.

Structurally the pulp is made up of the following elements:

(*a*) Odontoblasts.
(*b*) Connective-tissue cells.
(*c*) Intercellular tissue.
(*d*) Bloodvessels.
(*e*) Lymphatics.
(*f*) Nerves.

The Odontoblasts.—These are the specialized connective-tissue cells that form the dentin. They lie along the periphery of the pulp in contact with the dentin walls and send long protoplasmic processes into the dentinal tubules.

The Connective-tissue Cells.—These are stellate in form and resemble the connective-tissue cells in young, growing tissue. They are scattered throughout the pulp tissue.

The Intercellular Substance.—This is quite structureless and gelatinous in character. Scattered everywhere through it are the cells just described.

The Bloodvessels.—These enter the tooth through the apical foramen and the larger vessels travel through the center of the pulp, giving off many branches. These break up into capillaries which form a rich network about the periphery of the pulp. From these the blood is collected by veins that run with the arteries and pass out through the foramen. The walls of the bloodvessels in the pulp are extremely thin even in the arteries and larger veins. This condition renders the tissue particularly susceptible to inflammation.

The Lymphatics.—Within the last year Dr. Noyes has succeeded in demonstrating that there are lymphatic vessels in the pulp and that these are connected through the apical foramen with the lymphatic vessels and glands of the neck.

The Nerves.—Several trunks enter the tooth through the apical foramen and run through the center of the pulp giving off branches. These branches pass to the periphery and form a network at the base of the odontoblasts and secondary arborizations around each odontoblast. None of the nerve fibrils enter the tubules in the dentin. Sensation in the dentin is due, therefore, to the irritation of the protoplasmic processes of the odontoblasts which transfer these irritations to the nerve fibers in physiological contact with them.

Function of the Pulp.

(*a*) The formation of dentin.

(*b*) A sensory function. It responds to heat, cold, and gives the sensation of pain.

Secondary Dentin.—This is dentin that is sometimes formed after the normal amount of dentin has been laid down and the pulp has ceased to functionate. It is due to irritation of the pulp by some external agent and this organ responds by attempting to again perform the duties for which it was designed.

The Attachment of the Teeth.—As has been previously stated, the teeth are not to be considered a part of the osseous system of the body, as they bear no relation to it from a point of origin. Of what system then are they a part? It has been clearly proved that these organs are appendages of the skin that have through the processes of evolution become highly specialized into the form that we see them in the various animals and in man. The *simplest form of tooth* is seen in some of the fishes. It consists of a cone of enamel covering a calcified connective-tissue papilla containing tubules and closely simulating dentin. This in turn rests upon a second mass of calcified connective tissue like unto the cementum. Into this latter structure the fibers of the underlying tissue are built. To such a simple form of tooth no bone is in any way related. In the attempt to find from what structures the teeth were evolved it was noted that the dermal scales on the bodies of certain fish, *i. e.*, the shark and sturgeon, were but duplicates of the simple forms of teeth just described. This fact, together with other sufficient proof, left no question but that the teeth were really dermal appendages that had migrated into the mouth.

From this simple form of tooth attachment by fibrous tissue to underlying soft parts there are numerous variations of form and methods of attachment according to the work that the individual requires of his teeth and the amount of force exerted upon them in doing this work. So it is noted that as the food upon which an animal subsides becomes harder, the attachment of the teeth becomes firmer. To combat the force of displacement, roots were evolved and bone developed about them until the perfected form of support, as seen in man, was reached.

At first thought it might seem that the strongest way in which to hold a tooth in place would be to build the bone immediately against the root so as to lock the tooth absolutely in position. If this were done, however, the slightest blow upon the crown of a tooth would either fracture it at the gingival margin or so severely shock the pulp that its life would be forfeited. Furthermore, the transmission of the force of mastication to the bones of the head under such favorable conditions would be productive of severe traumatic shock to the brain. Nature avoids all of this by placing between the root of the tooth and the bone of the alveolar process a fibrous membrane, the function of which is to literally suspend the tooth in its socket. Thus it not only retains the tooth perfectly but also acts as a cushion. This membrane is called the *peridental membrane* and may be considered as the most important of all the *dental* tissues. Why? Because it makes no difference how perfectly formed a tooth is or how carefully its contour be restored by dental operations correcting the ravishes of caries, if this membrane, that bears all the stress during mastication, is not in perfect health, that tooth will be proportionately useless.

The Peridental Membrane.—Definition.—The peridental membrane may be defined as that tissue which fills the space between the surface of the root and the bony wall of its alveolus, surrounds the root occlusally, from the border of the alveolus, and supports the gum. (Noyes.)

From this definition it will be noted that this membrane not only covers that portion of the root that is within the alveolus but also that part between the top of the alveolus and the gingival line. Indeed this latter portion may be considered as the *most important part of the membrane,* because it is here that the initial lesions which eventually lead to the loss of the tooth, occur.

Structurally the peridental membrane is made up of the following elements:

- White fibrous connective tissue.
- Four varieties of cells:
  - *Fibroblasts*
  - *Cementoblasts.*
  - *Osteoblasts.*
  - *Osteoclasts.*
- Bloodvessels.
- Nerves.
- Epithelial structures.

The White Fibrous Connective Tissue.—A careful study of the distribution of this tissue is of absolute necessity if one is to realize the important role that the peridental membrane plays in maintaining the tooth in a functionating condition.

The fibrous tissues may be divided into two classes of fibers: (*a*) The principal and (*b*) the indifferent. The first group is the one concerned in the support of the tooth, the other fibers simply fill the spaces between the principal fibers and support the bloodvessels.

The Principal Fibers.—These are built into the cementum in the form of fairly large bundles. Upon emerging from the cementum they break up into smaller bundles, bridge across the interspace and are again gathered together to be built into the bone of the alveolar process or distributed to support the gum. This is the general arrangement. The direction, however, that these fibers take as they pass from their point of origin in the cementum to their insertion in the bone or gum is modified in various parts of the membrane and is in definite relation to the force brought to bear upon the tooth as it performs the work of mastication and upon the pressure exerted against the supported gum tissue. This adaptation is the more perfect in that this arrangement is the result of this force and the force not secondary to the building of the fibers. This is demonstrated more clearly perhaps if it is borne in mind that the cement-building cells are constantly at work shifting the attachment of fibers whenever there is a change in the direction of force exerted on the tooth. If the tooth is changed in position, the arrangement of the fibers of the membrane will be varied to accommodate any changes in the force of mastication.

For the purpose of studying the arrangement of the principal fibers, the membrane may be divided into three segments: (*a*) the gingival, that part between the border of the alveolar process and the gingival margin; (*b*) the alveolar, that part situated between the border of the process and the apex; and (*c*) the apical, that portion in relation to the apex of the root. (Fig. 39.)

Arrangement of the Fibers in the Gingival Portion.—There are four sets of fibers in this area. The *first group* arises from the highest point of attachment occlusally on the root, passes from this at more or less of a right angle, then takes an occlusal curve and passes into the gum tissue to be lost among the fibers of the connective tissue that supports the epithelium of the mucous membrane.

The *second group* arises from an area just below the fibers of the first group, passes out from the cementum at right angles and continues for sufficient distance into the gum tissue to give this perfect support. On the lingual side these fibers run a longer course than on the labial because the lingual gum receives a greater shock in chewing than does the labial. The distribution of this group of fibers on the *approximal side* is of extreme importance. Here they pass across the intervening approximal space to the adjoining tooth and are built into the cementum of this tooth. Each tooth receives and gives off fibers on the approximal side which are built into its cementum. These, as they pass across the space, are closely interwoven, forming a basket-work structure that supports the overlying gum in a most perfect manner. The *third group*. A little more rootward to the second group is another set of fibers that soon after passing from their attachment in the cementum are inclined apically. These form a very strong bundle of fibers. On the labial and lingual sides they pass to the outer surface of the alveolar process and are attached to the periosteum covering the bone here. On the proximal side they either pass to the

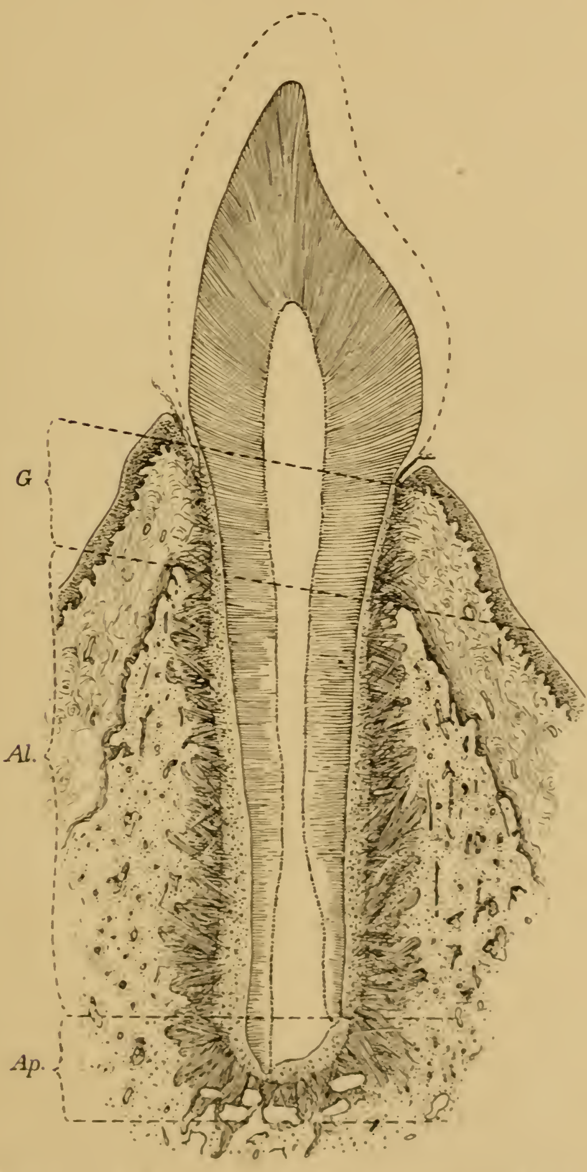


FIG. 39.—Diagram of the fibers of the peridental membrane: *G*, gingival portion; *Al.*, alveolar portion; *Ap.*, apical portion. (From a photograph of a section from incisor of sheep.) (Noyes.)

cementum of the adjoining tooth or are built into the upper surface and sides of the bone that intervenes between the teeth. These fibers resist any force that tends to pull the tooth from its socket. They form what is known as the dental ligament.

The *fourth group* are arranged like a constrictor muscle around the gingival margin and keep the gum tissue in close contact with the neck of the tooth.

Arrangement in the Alveolar Portion.—Here are found three areas of variation in direction of the fibers. *First:* The fibers coming off from the cementum at the level of the top of the alveolar process pass at right angles across the intervening space to be inserted into the bony walls of the process. This arrangement is continued down the root of the tooth nearly one-third of the distance to the apex. These fibers arise from the cementum in strong bundles and then break up into fan-like forms as they cross the space to be inserted into the bone. In transverse sections of the root at this level it is noted that the fibers that come off from the angles of the roots do not pass immediately across the space but are deflected to right and left. These are the fibers that resist any force that tends to rotate the tooth in its socket.

Second: As the lower portion of the previously considered area is approached the fibers, after leaving the cementum, begin to pass occlusally and are inserted somewhat higher up on the wall of the alveolus. This arrangement is continued until the apical end of the tooth is reached. This area is large and the fibers are strong because they have to resist the greatest force exerted in mastication, *i. e.*, the thrust force as the jaws are closed. By these fibers the tooth is actually suspended in its alveolus.

Third: At the lower portion of the apical third of the root the fibers again begin to take a more direct course from the cementum to the bone until they are passing directly across, as noted in the upper third.

The Arrangement in the Apical Portion.—Here the fibers after passing from the cementum radiate in all directions before being inserted into the bone. In this way the apical space is filled with a mass of fibrous tissue.

The Cells.—*Fibroblasts.*—These are the cells that have formed the fibers and are looking after their welfare. They are scattered throughout the entire membrane.

Cementoblasts.—These are the cementum-forming cells and lie in contact with this tissue between the points of origin of the fibers. As they form the cementum some of the cells surround themselves with it and then take the name of cement cells or corpuscles. They also build into the cementum the fibers of the membrane.

Osteoblasts.—These are the bone-forming cells and have their station on the bony walls of the alveolus. They are active in forming the bone of the alveolar process that is in juxtaposition to the roots of the teeth. They too become bone cells when they have surrounded themselves with this tissue. The attachment of the fibers of the membrane into the bone is performed by these elements.

Osteoclasts.—These are the cells that eat away the bone or cementum when there is a demand for this process. Through their action the fibers of the membrane are detached at any given area. This occurs during the absorption of the roots of the deciduous teeth and it is these cells that are responsible for this process. They are also used when nature believes that the bone in any given place is too thick and heavy for the strain brought to bear upon it. If so, these cells are brought into activity and destroy the thick bone by forming marrow spaces within it. This occurs in the formation of the alveolar process and accounts for its cancellous or spongy character.

Bloodvessels.—The peridental membrane has a very rich supply of blood. The arteries enter the apical space from the bone beneath. They then give off branches which pass into the pulp cavity to supply the organ therein. The main branches pass occlusally in all directions through the peridental membrane. They lie nearer the wall of the alveolus than the cementum. As they pass upward they receive from and give off branches to the bone of the alveolar wall. They end by anastomosing with the bloodvessels of the gum tissue and help supply this area. From this it is noted that the blood supply of the gums and peridental membrane is intimately related so that stimulation of gum tissue by massage and brushing will in turn stimulate the peridental membrane—a fact that is of the greatest importance in the treatment of lesions of this latter structure.

The Nerves.—These have the same point of entrance and the same distribution as the bloodvessels that have just been described. It is important to note that these nerves give to the peridental membrane the *sense of touch.* This sense is well developed, for the lightest contact is immediately recognized.

Epithelial Elements.—As the function of these structures is still a mystery it is sufficient in this text to note that such tissues are present but that their real significance still remains unknown.

The function of the peridental membrane.

(*a*) A physical function, *i. e.*, the maintaining of the tooth in the socket.

(*b*) A vital function, manifested through the agency of its cells in the formation of cementum and bone.

(*c*) A sensory function in that it supplies the sense of touch to the tooth.

Changes in the Membrane with Age.—When the tooth first erupts the space between the root and wall of the alveolus is relatively wide. Each year finds this becoming smaller and smaller because of the formation of new lamellæ of cementum on the one side and of bone on the other. The peridental membrane grows proportionately thinner as it is thus encroached upon. However, there is always membrane present no matter what the age of the individual may be. In other words, the bone and cementum never come in immediate contact with each other. This thinning of the membrane makes it less resistant to irritations and so predisposes inflammatory conditions. Hence diseases of the peridental membrane are more frequently found after adolescence.

The Alveolar Process.—As has been perviously emphasized, the bone of this process is built secondary to the formation of the teeth or rather coincident to their eruption. It is a product of function and is arranged as to its structure in a way that will best resist the forces that are brought to bear upon it. In the *upper jaw* we find a dense, hard layer of bone about the necks of the teeth labially and buccally. In the incisor and cuspid region where much force is exerted upon the whole length of the roots the bone is quite thickened over their entire labial surfaces. This is well demonstrated in those lower animals that use these teeth for seizing and tearing their prey. Over the buccal roots of the bicuspids and molars it is very thin. Lingually, all the teeth of the upper arch are well supported.

In the *lower arch* again is found the compact bone about the necks of the teeth and their roots well supported buccally, as most of the strain is in this direction.

The *great mass of bone* of both the maxilla and the mandible is made up of the cancellated variety about the periphery of which is a layer of thick, dense bone. The wall of each alveolus joins this thickened layer at its upper border. Below this point of union the wall of the alveolus is surrounded with cancellated bone so that the alveolar process as a whole is quite elastic and springy. In connection with our reference to bony tissue it is well to mention the fact that this is living tissue, a specialization of the connective tissues, adapted for perfect support and that it is ever throughout life undergoing constant change as a result of the mechanical forces brought to bear upon it. By virtue of the ability to make such changes, nature is able to meet any requirement that is demanded, even though it be far different from the original condition for which the bone was built. So in examining a specimen of bony tissue under the microscope various forms of bone cell activity are seen going on, representing different stages of bone formation and absorption.

Tooth Formation.—The first sign of the formation of teeth is seen in the embryo at about two and a half months. Along the top of each arch (upper and lower) there is seen a heaping up of the cells of the outer layer of tissue. If a cross-section is made of the arch, it will be noted that these cells are also dipping down into the underlying tissue. This formation is known as the *dental ridge*. From the lingual side of this ridge a shelf-like growth is formed called the *lamina*. At intervals along the lamina corresponding to location of each tooth little buds grow down from it. The under surface of these buds becomes indented, taking on the appearance of an inverted cup. This structure is now known as the *enamel organ* (Fig. 40), and will soon begin to lay down enamel along its inner surface. The cells lining this surface are the enamel cells and are active in the formation of this substance. The enamel organ is of epithelial tissue origin.

As the enamel organ is forming, the cells of the tissue into which it grows begin to take on activities. As fast as the infolding of the base of the enamel organ takes place the indentation is filled in with these active underlying tissues until a papilla is formed. This is known as the *dental papilla* (Fig. 40). This structure is of connective-tissue origin and will become active in the formation of the dentin. Growth of the papilla continues until it has assumed the shape of the crown of the tooth to be formed. To this structure formed by the enamel organ and dental papilla is given the name of *tooth germ*.

Fig. 40.—The enamel organ. The outer tunic connected to the lamina by the cord; the dental papilla growing up into the cap. The spaces are shrinkage spaces. (Noyes.)

After the dental papilla has been formed the cells at its base develop fibrous tissue which grows up and around the outer side of the enamel organ and over its top so that the tooth germ is enclosed in a fibrous sac. This combination of structures, *i. e.*, the fibrous wall, the papilla and the enamel organ constitutes the *dental follicle*. This is completed by the end of the twelfth week.

Just before the enclosure takes place a secondary bud is given off from the enamel organ, usually near its point of origin from the lamina, which grows downward to become the enamel organ of the permanent tooth (Fig. 41).

Soon after the formation of the dental follicle the bone of the jaw below this structure sends up processes which pass to the lingual and labial side of the follicle. Later bony growth appears on the proximal sides and finally the top is covered over. This bony structure is what

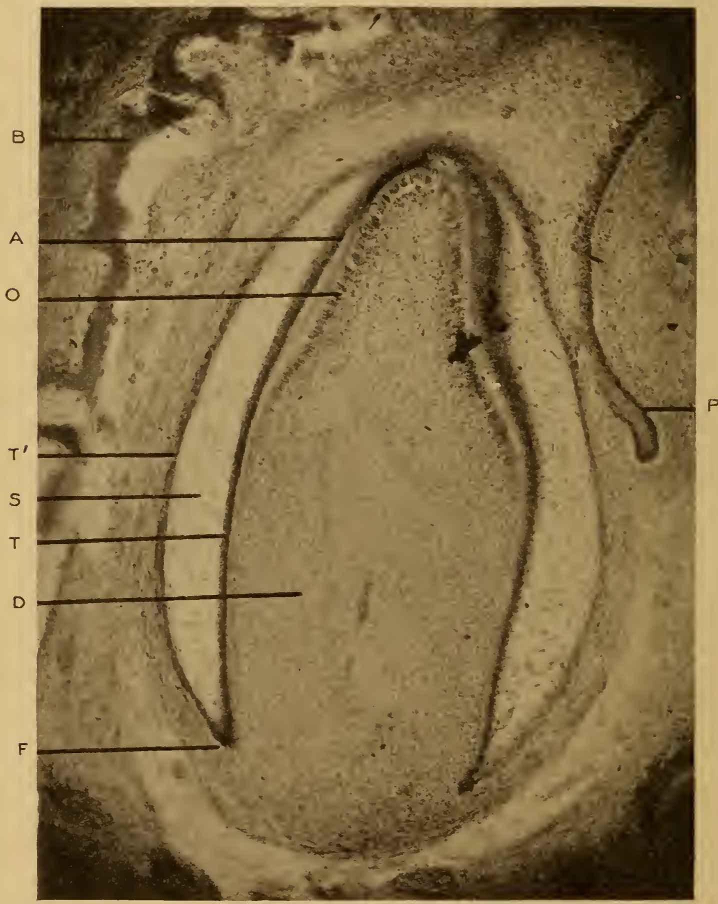


Fig. 41.—The tooth germ showing the bud for the permanent tooth at *P*. Calcification is just beginning: *F*, follicle wall; *D*, dental papilla; *T*, inner tunic; *T′*, outer tunic; *S*, stellate reticulum; *O*, odontoblasts; *A*, ameloblasts; *B*, bone. (Noyes.)

is known as the *dental crypt* and simply serves as a protection to the forming tooth. This formation persists until the entire crown is developed and the tooth ready to erupt when the top is absorbed and the tooth passes into the mouth.

At about the sixteenth week the dentin and the enamel begin to form, the former on the outer edge of the dental papilla and the latter on top of this dentin.

The roots of the teeth do not appear until the tooth begins to take on the process of eruption. At this time also the first of the cementum is seen. This is formed by cells in that fibrous tissue that grew up and around the enamel organ to complete the follicle. This fibrous tissue now may be considered as the peridental membrane. Coincident with the formation of cementum by the cells on the inner side of this membrane there is a deposit of bone laid down by the osteoblasts on the other side of the membrane. This is the beginning of the alveolar process.

The first permanent molars are the only permanent teeth for which the enamel organ arises directly from the lamina. The enamel organs for the second and third permanent molars arise from the buds of the first and second permanent molars respectively.

THE DEVELOPMENT OF THE JAWS.

While it is impossible in the space alloted this subject to go into detail regarding the growth of the jaws, yet it is quite necessary that the dental hygienist should know briefly the plan upon which nature builds under normal conditions. For an exhaustive study of this subject the student is referred to Dr. Noyes's text-book, *Dental Histology and Embryology.*

In a comparison of the skull of an infant at birth with that of an adult it is noted that as growth proceeds there is practically twice as much development below the nasal spine of the frontal bone as above it. Passing in our study to this region of greatest change it is seen that in the adult it can be divided into thirds, the upper of which is occupied by the nasal cavity and the lower two-thirds by the organ of mastication. When, however, an attempt is made to study the child's head from this point of view it is found that it is impossible to so divide the head for there is a fusion, as it were, of the upper two-thirds, and that territory that is entirely nasal in the adult, is here more than half given over to the developing tissues of the organ of mastication. To be more specific, all that part of the nasal cavity which lies below the lower border of the orbits is literally lined with tooth germs. From this study it may be deducted that the great *downward* growth in the lower half of the head is due primarily to the formation and subsequent eruption of the teeth, and secondarily to a continued growth of bone thrown out to act as a supporting structure for these organs. This downward growth begins with the eruption of the deciduous denture and continues until all the permanent teeth anterior to the first molars are in position. After the completion of the deciduous denture two new directions of growth manifest themselves, a *lateral* or expanding growth to allow for the difference in size between the teeth of the deciduous and permanent dentures, and a *forward* one to make room for the developing permanent molars. This development continues until all the teeth are in position and occlusion is established.

CHAPTER III.

PHYSIOLOGY.

By ALEXANDER M. PRINCE, M.D.

Definition.—*General physiology,* a branch of the biological sciences, is concerned with the study of function in all living organisms. *Human physiology,* one of its subdivisions, deals with the functions of the body of man.

The term *function* is applied to all the activities or life processes of the various parts of the body, and in a broader sense includes the interrelations of these activities in the economy of the individual as a whole. As all the reactions of the body are dependent on physical and chemical phenomena, function may be further *defined* as the chemistry and physics of the living body.

From the study of anatomy it has been found that the structural unit of every living thing is the cell and that cells of the same type enter into the formation of tissues which in turn constitute the different organs. Likewise, *the unit of function is the cell,* as the behavior of any tissue or organ depends upon the characteristics of its cells.

The Cell.—The *typical cell* consists of a semifluid, jelly-like substance called *protoplasm.* This substance is a complex chemical combination of the following elements: nitrogen, carbon, oxygen, hydrogen, sulphur and a trace of phosphorus.

The protoplasm is divided into the *cytoplasm* which forms the body proper of the cell and a spherical or oval body, usually found in the center of the cell, called the *nucleus.*

The majority of cells contain but one nucleus, although not infrequently two or more are present. In the higher organisms an exception to this rule is found in the red blood cell, the nucleus of which is lost in the process of development.

The *nucleus* is an essential constituent of the cell, for if a cell is divided by section into a nucleated and non-nucleated portion, the first regenerates to a complete cell, whereas the non-nucleated portion soon dies. The formation of certain substances in the cytoplasm are prevented by removal of the nucleus and furthermore, reproduction cannot take place in its absence. On the other hand, the nucleus is dependent on a certain amount of cytoplasm, for if completely isolated, it also perishes. It is therefore evident that both the nucleus and cytoplasm are essential to the life processes of the cell.

Properties of Protoplasm.—Protoplasm is not only very complex, but also very unstable. In the presence of oxygen, protoplasm undergoes chemical changes with the formation of simpler substances. This process is known as *oxidation* and is essentially a burning up of protoplasmic material. The result of this combustion is the production of *energy* which manifests itself as heat, motion, etc. The end-products of oxidation, which are known as *waste materials,* exert a poisonous influence on the cell if allowed to accumulate, but means are available for their removal by the function of *excretion.* On the other hand, the waste resulting from the evolution of energy must be constantly replaced, otherwise death of the cell would eventually follow. This waste can only be repaired by the absorption of new material and it is for this reason that food is required. The process of breaking down in the cell which accompanies the liberation of energy is known as *catabolism;* the repair and growth of the cell is known as *anabolism;* and these two processes considered together are included under the term *metabolism.*

Most foods as found in nature are not in a condition to be absorbed and assimilated by the cell until especially prepared by chemical processes. This function of food preparation is present in certain cells and is known as *digestion.* An important function found in animal life is *motility* or the ability to perform movements which result from changes in the shape of the cell. This form of cellular activity is associated with the function of *irritability,* by which the organism is enabled to perceive and react to external changes. As all beings originate from a preëxisting cell, the function of *reproduction,* which permits such perpetuation of species, must be considered.

To recapitulate then, it is noted that there are certain *fundamental properties or functions* common to all forms of living matter: metabolism, motility, irritability, and reproduction. These activities are found in a very primitive form in single-celled organisms and so may be advantageously studied in one of these, for example, the ameba.

The Ameba. The ameba is an example of the simplest form of animal life and consists of a single cell. It is found in stagnant bodies of water and moves about slowly by the extension of finger-like processes resulting from the flow of its protoplasm. This form of motility is known as *ameboid motion.* This organism also presents evidence of irritability, for it will respond to external influences, moving toward food particles and away from harmful substances.

This ameboid motion also serves as a means of capturing particles of animal and vegetable matter upon which it feeds, two protoplasmic processes encircling the food particle and forcing it into the semifluid interior of the animal.

The food is then slowly digested by juices formed in the protoplasm and is distributed to all parts of the cell where it is utilized for repair and the storage of energy while the undigestible portions of the food are finally extruded from the cell body. These reactions represent the functions of digestion, assimilation and excretion. The ameba absorbs the oxygen necessary for energy production from the water in which it lives and gives off carbon dioxide. This function is known as respiration. In this animal, reproduction is very simple, taking place by division of the nucleus and cell body.

It is noted from the ameba that all functions may be present in one cell, but as the scale of evolution is ascended animal forms consisting of many cells are met with. In these it is found that all functions are not possessed alike by all the cells, but that there is a *division of labor*, certain groups of cells becoming better adapted along particular functional lines. This specialization of cellular function cannot be better observed than in man, for the human body is essentially a large colony of cells the individuals of which have special duties to perform.

The first physiological process that demands attention is that of *nutrition* or *alimentation*, as it is called. This is studied under four divisions, *i. e.*, digestion, absorption, assimilation, and elimination or excretion.

PHYSIOLOGY OF DIGESTION.

The human body in the performance of its functions is constantly losing material.

Every form of activity, whether the contraction of a muscle, the transmission of an impulse through a nerve or the secretory processes of gland cells, is accompanied by catabolic or breaking down changes in the cell protoplasm. These changes result mainly from the combination of oxygen, carried in the blood, with complex chemical substances in the cell. The simple products arising from the destruction of the cell substance, being no longer of value to the cell, are removed by the process of excretion. In order to maintain the activity of the tissues, this waste of substance must be constantly replaced by suitable new materials, which are called *foods*.

Classification of Foods.—Foodstuffs are divided into two general classes: (I) *nitrogenous* and (II) *non-nitrogenous*.

I. The nitrogenous foodstuffs include the *proteins* and the *albuminoids*.

The *proteins* are found in the protoplasm of all forms of vegetable and animal life and are chemical combinations of nitrogen, carbon, oxygen, hydrogen, sulphur and phosphorus. Protein has been called the "essential" foodstuff, as it contains the necessary elements for the repair of the body cells.

The *albuminoids*, chemically allied to the proteins, are derived from connective tissues (bones, tendons, etc.), but are unimportant as foods, owing to the difficulty with which they are absorbed from the alimentary tract.

II. The non-nitrogenous foodstuffs, as the name implies, do not contain nitrogen and include the *carbohydrates*, the *fats*, the *mineral salts* and *water*.

The *carbohydrates* consist of carbon, oxygen and hydrogen in combination and are mainly derived from the vegetable world. This division includes the starches and sugars. These substances are readily oxidized in the body and for that reason have great energy-producing power.

The *fats* consist of the same elements found in carbohydrates and include the oils and fats derived from animal and plant life.

The most important *mineral salts* required for the needs of the body are the chlorides, phosphates, sulphates and carbonates of sodium and potassium and the phosphates and carbonates of lime and magnesium. Of these substances the chloride of sodium (common salt) is the most essential. Iron and iodin are also necessary in small quantities.

Water is a chemical compound of hydrogen and oxygen and next to air is the most important substance required for the maintenance of life. Water constitutes 70 per cent. of the body weight and is found in all the tissues and fluids of the body. It also acts as a solvent for many substances which could not be otherwise absorbed or excreted.

TABLE I.—FOODSTUFFS.

				Occurrence.
1. Nitrogenous	Proteins		Albumin	white of eggs, milk, blood, etc.
			Casein	milk and cheese.
			Myosin	muscle tissue (meat).
			Syntonin	
			Vitellin	yolk of eggs.
			Gluten	cereals (flour).
	Albuminoids		Chondrin	cartilage.
			Gelatin	in bones and other connective tissue.
2. Non-nitrogenous	Carbohydrates	Starches		in all cereals, potatoes, unripe fruits.
		Sugars	Sucrose	sugar cane.
			Glucose	fruits.
			Maltose	malt.
			Lactose	milk.
	Fats		Stearin	found combined in animal and vegetable fats and oil.
			Palmitin	
			Margarin	
			Olein	
			Lecithin	in yolk of egg and nervous tissue.
	Salts			in vegetable and animal tissues and directly from mineral world.
	Water.			

Most of the foodstuffs as they occur in nature are not in a condition to be utilized by the body cells until especially prepared by chemical processes. This food preparation or digestion is accomplished by specialized cells associated with the organs of the alimentary system.

Of all the materials used as foods, water and the majority of the salts are *diffusible* and therefore readily absorbed by the cells lining the alimentary canal. On the other hand, the proteids, carbohydrates and fats are *not diffusible,* that is, they will not pass through an animal membrane until their chemical nature has been changed. This process of making indiffusible substances suitable for absorption is brought about by the action of *enzymes* secreted by the cells of glands which empty into the alimentary canal.

Properties of Enzymes.—Although little is known of the chemical composition of enzymes, these substances may be recognized by the following facts:

1. They are manufactured and secreted by living cells.
2. A very small quantity of an enzyme, without undergoing any special change in itself, will act upon enormous amounts of foodstuffs.
3. Their action is selective, that is, they will only act upon special substances, *i. e.,* ptyalin only digests starches and has no effect on protein or fats.
4. Their action depends on the reaction of the medium, *i. e.,* ptyalin only exerts its effects in alkaline solutions, its chemical action being arrested immediately in the presence of acids. Pepsin, on the other hand, acts in an acid medium.
5. Their activity depends on the temperature, being most effective at body temperature, ceasing to act in the cold, and being permanently stopped at high temperatures, such as would result from boiling.

Alimentation.—The alimentary system consists of a long tubular channel running through the body. Emptying into it at different levels are the ducts of the digestive glands, the cells of which secrete digestive fluids of specific qualities, some acting on proteins, others on fats and carbohydrates. Through the motility of this alimentary tube the food is propelled and progressively brought in contact with these fluids. Chemical transformations take place whereby the food is prepared for absorption, the undigestible portions remaining in the digestive tract from which they are later expelled.

Mastication.—The first process of alimentation is *mastication* or the chewing of food. The food introduced into the mouth is ground by the teeth and mixed with the secretion of the *salivary glands.* During the process of mastication the food is finely reduced so that it will offer a greater surface for the action of the digestive juices and is at the same time moistened with saliva so that it can be more readily swallowed. Furthermore, if any starches are present, they are in part transformed into diffusible sugars by the action of the salivary enzymes.

The Salivary Glands.—The *digestive glands of the mouth* occur in pairs and are named from their location, the parotid, the submaxillary and the sublingual. The secretion of these three groups of glands, mixed with the mucus of microscopic glands which are scattered throughout the mouth, is called *saliva.*

Each gland is made up of secreting cells arranged in the form of small sacs which communicate by fine ducts or tubules. These tubules join to form the larger ducts which open into the mouth. These glands are supplied with a rich network of bloodvessels and nerves. Their nervous control is beautifully shown by the marked secretion which occurs at the sight or smell of pleasing foods.

The mixed *saliva* of the glands of the mouth consists in great part of water and is of an *alkaline reaction.* Among its constituents are *mucin,* the substance which gives the saliva its slimy character and an enzyme known as *ptyalin* to which the partial digestion of starches is due.

The food after being thoroughly masticated and mixed with saliva is forced into the *pharynx,* a funnel-shaped muscular bag, by the act of deglutition. By the contraction of the pharynx the food is then pressed into the *esophagus.* The latter structure is a tube which conveys the food from the pharynx to the stomach by a progressive wave-like contraction of its muscular coats. This type of muscular action which occurs also in the stomach and intestines is known as *peristalsis.*

Gastric Digestion.—The *stomach,* continuous above with the esophagus and below with the small intestines, is a muscular bag having a capacity of about three pints. Its internal surface is lined with secreting glands the cells of which are arranged in the form of simple tubular structures. The cells forming these tubules are of three types; those lying near the opening of the glands secrete *mucin,* the other two varieties secrete *hydrochloric acid* and the enzymes *pepsin* and *rennin.*

At the point of junction with the small intestines the stomach is furnished with a muscular ring continuous with its muscular coats. This ring acts as a valve and is called the *pyloric sphincter.* The *function* of this structure is to prevent the further progression of the food until sufficiently digested in the stomach.

The Gastric Juice.—The secretion of the stomach, known as the *gastric juice,* is a clear, acid fluid consisting of water, hydrochloric acid, to which the acidity of this secretion is due, and two important enzymes, pepsin and rennin. These two enzymes, unlike ptyalin, produce their effects only in an acid medium.

Pepsin transforms the indiffusible protein foodstuffs into peptone. Peptone differs from undigested protein by its great solubility and the ease with which it passes through animal membranes. In this way peptones are readily absorbed by the cells lining the alimentary canal and can be then transferred to the blood and carried away to supply the needs of nearby and distant cells.

Rennin is an enzyme which acts on milk by precipitating the milk protein. This protein, known as casein, is indiffusible. After being precipitated it is then converted into peptone by the pepsin.

The gastric juice does not digest fats or carbohydrates, and the digestion of starches previously begun in the mouth is soon arrested by the acid reaction of the gastric secretion.

The stomach by the contraction of its muscular walls, churns the food so that it is thoroughly mixed with the secretions, thus hastening the process of digestion. The food, when gastric digestion is completed, is reduced to a grayish liquid material known as *chyme.* At this stage the pyloric sphincter relaxes and allows the gradual passage of the stomach contents into the small intestines.

Although the stomach is richly supplied with bloodvessels, only a very small portion of the digested foods are absorbed into the blood from this organ, so that the stomach, like the mouth, is concerned principally with the preliminary preparation of food.

The Small Intestine.—Th e*small intestine,* where final digestion and absorption take place, is a muscular tube, the mucous membrane of which is thrown into folds so as to offer a greater surface for absorption. This mucous membrane consists largely of finger-like projections called *villi,* between which lie tubular glands (glands of Lieberkühn) which produce a secretion known as the *succus entericus.* This secretion contains water, mucin and some enzymes concerned with the digestion of protein and the transformation of indiffusible carbohydrates into dextrose.

In the upper part of the small intestine (the duodenum) open the ducts of two large glands, the *liver* and the *pancreas.*

The Liver.—The *liver* is a large gland which secretes an alkaline, golden-yellow fluid known as *bile.* The principal *function of the bile* is to neutralize by its alkalinity the acid chyme derived from gastric digestion, and thus prepare it for the action of the pancreatic enzymes which are effective only in an alkaline medium. The bile contains pigments and salts. The *bile salts* are especially important, as they aid in the digestion and absorption of fats in the presence of the pancreatic secretion.

The Pancreas.—The *pancreas* is a gland much larger but similar in structure to the salivary glands. Its cells secrete an alkaline fluid which contains three important enzymes, *trypsin, amylopsin* and *steapsin.*

Trypsin has an action similar to pepsin, as it transforms proteins into peptones, but in this case only in an alkaline medium.

Amylopsin is similar in its action to ptyalin, transforming starches into sugar.

Steapsin is the enzyme concerned with the digestion of fats. Under its influence fats are broken up into *glycerin* and *fatty acids.* Glycerin is readily absorbed by the intestinal cells and the fatty acids combine with the alkali of the pancreatic juice and bile to form soaps which are very diffusible. The rest of the fats which are not changed in this manner are emulsified or reduced to fine division by the action of the soaps. The fat emulsion and soaps are then in a form which can be absorbed by the villi.

As in the stomach, the food is kept in motion by the peristalsis of the intestines so that finally the food is distributed throughout the small intestine for *absorption*. The contents of the small intestine when digestion is complete are known as *chyle* and have a creamy color owing to the presence of finely divided fat.

The original food which was taken into the mouth as unabsorbable proteins, carbohydrates, and fats is now converted into peptone, sugar, glycerin, soaps and emulsified fats, any one of which can readily be absorbed.

TABLE II.—DIGESTION IN THE ALIMENTARY CANAL.

Place.	Secretion.	Source.	Enzyme.	Reaction of medium.	Foods acted upon.	Final products.
A. Mouth	Saliva	Secreting cells of salivary glands	Ptyalin	Alkaline	Starches	Dextrin, maltose.
B. Stomach	Gastric juice	Peptic glands	Pepsin	Acid	Proteins	Peptones.
			Rennin	Acid	Milk	Casein precipitated (milk curds) which pepsin transforms into peptone.
C. Small intestines	Pancreatic juice	Pancreatic cells	Trypsin	Alkaline	Proteins	Peptones.
			Amylopsin	Alkaline	Starches, sugars	Maltose.
			Steapsin	Alkaline	Fats, oils	Fatty acids, glycerin (emulsified fats, soaps).
	Bile	Liver cells	None	Alkaline	Aids pancreas in fat digestion.	
	Succus entericus	Intestinal gland cells	Maltase	Alkaline	Indiffusible sugars	Dextrose.

PHYSIOLOGY OF ABSORPTION.

Practically all *absorption* takes place in the small intestine. This proceeds in two different ways. (1) Absorption into the lymphatics by means of the villi, and (2) direct absorption into bloodvessels, tributaries of the portal circulation.

Fats are absorbed by the *lymphatics;* sugars, peptones, salts, etc., by the *bloodvessels.*

The *villi* are small finger-like structures containing a lymphatic channel surrounded by a network of fine bloodvessels, the whole being covered by a single layer of columnar shaped cells. These lymphatic channels or *lacteals* of the villi connect with larger lymphatic vessels which eventually empty into the general circulation by means of a large lymphatic vessel known as the *thoracic duct.*

Fats are absorbed by the cells lining the villi and passed into the central lymphatic channels. They are then carried through this system of vessels and thrown directly into the blood stream to be distributed to all parts of the body.

The intestinal tract is furnished with a rich network of fine bloodvessels which lies directly under the cells lining the intestines. The bloodvessels or capillaries forming this network fuse into larger vessels which empty into the liver by means of a large vein called the *portal.*

Peptones, sugars, salts and *water* pass into these bloodvessels and hence are taken through the liver before their final distribution to the body cells.

PHYSIOLOGY OF ASSIMILATION.

Peptones, after undergoing further changes in the liver, are distributed to all the cells by the general circulation and there are used for the *repair* of the cell protoplasm.

The *sugar* (dextrose) in excess of the immediate requirements of the body, is stored in the liver cells as *glycogen.* This substance is an insoluble sugar formed from dextrose by the liver cells with the aid of an internal secretion furnished by the pancreas. This glycogen is retained in the liver until called for by the tissues when it is reconverted into dextrose and carried away by the blood stream.

If carbohydrates are taken in excess, so that the limit of storage is reached in the liver, sugar is converted by connective-tissue cells into fat which is stored in various parts of the body, under the skin, about the mesentery, etc.

Fats are utilized like sugar in the production of energy, work, animal heat, etc., and if in excess are also stored as fats for future use.

The Removal of Waste Products.—By the peristalsis of the small intestine the undigestible portions of the food are gradually carried to the large intestine. The contents of the latter structure are practically free from absorbable substances. This undigested food undergoes bacterial changes, becoming acid in the process, while the large amount of water present is removed by absorption. It is then known as the *fæces* and as such is finally expelled from the body.

The *physiology of elimination or excretion* is considered in detail on page 122.

THE PHYSIOLOGY OF RESPIRATION.

Chemical Changes.—When *oxygen* combines chemically with *carbon* a gaseous compound is formed known as *carbon dioxide.* This chemical reaction (oxidation) is always accompanied by the liberation of energy which appears as heat. By suitable means heat may be converted into some other form of energy, for instance, mechanical work.

These changes are well illustrated by the steam engine in which coal, a substance rich in carbon, combines with the atmospheric oxygen to form carbon dioxide, the result of this oxidation being to liberate energy in the form of heat. This heat applied to the boiler converts the water it contains into steam, and the pressure of the latter is then transferred to the functionating parts: piston, piston rod, wheel, etc., so that the energy derived from a chemical process, the burning of coal, is transformed into mechanical work.

In the living cell are found similar processes occurring in a modified form. In fact every cell is a *minute chemical engine,* burning fuel and liberating energy. In the cell the *fuel* consists of carbonaceous materials in the protoplasm which have been derived from the carbohydrate, fat and protein foodstuffs.

This *carbon-rich* material combines with *oxygen* absorbed from the surrounding medium of the cell and *carbon dioxide* is formed. This chemical reaction, as in the steam engine, is associated with the evolution of energy which appears as *heat* (animal heat) and *work,* the latter manifesting itself in different forms of activity according to the structure and the functional capacity of the cell.

Although many other chemical activities occur in living cells, *oxidation* is by far the most important of these. Deprived of oxygen, cells soon lose their functionating powers, and as life is absolutely dependent on the proper maintenance of functions, it is evident that oxygen must be constantly supplied to all the body cells.

Carbon dioxide, the final product of oxidation, is no longer of value to the cell, and like all excretory products acts as a poison if allowed to accumulate in the medium in which cells live. Therefore some means must also be available to remove carbon dioxide as rapidly as it is formed.

The function through which oxygen is supplied to the tissues and carbon dioxide removed is known as *respiration.*

In a *single-celled organism,* such as the ameba, no special organs are required for this interchange of gases. Oxygen is derived from the water in which this animal lives by direct absorption into the cell and carbon dioxide is excreted into the same medium.

In *higher animals* the same processes take place, for the body cells, like the ameba, live in a fluid medium which is represented by the blood and lymph. Each cell obtains its oxygen from the circulating blood and the carbon dioxide is excreted in these body fluids. But the blood must carry a constant supply of oxygen and at the same time some provision must be made to remove the carbon dioxide which would otherwise accumulate and exert a noxious influence on the tissues. This is accomplished in higher forms of life through the agency of the lungs.

The *air* is a mixture of three gases, oxygen, nitrogen and carbon dioxide. During the process of respiration this air is drawn into the lungs where, owing to the structure of these organs, the gases are brought into intimate contact with the circulating blood.

It will be seen under the physiology of the circulation that the blood, after having been in contact with the tissues, is carried to the lungs. There the carbon dioxide formed by oxidation in the cells is thrown off and a new supply of oxygen is absorbed by the blood to replace that part of the oxygen which has been utilized by the body cells. After this interchange the now purified blood leaves the lungs to be redistributed throughout the body.

The air in the lungs must also be changed at frequent intervals, otherwise there would be an insufficient supply of oxygen for the blood to absorb while the carbon dioxide in the blood could not be eliminated. It is for this purpose that nature provides the respiratory act, which is simply an alternate inflation and deflation of the lungs, by virtue of which the air in these organs is constantly renewed. *Respiration* is therefore divided into two phases: *inspiration*, during which the external air is drawn into the lungs; and *expiration*, during which air, now deficient in oxygen and laden with carbon dioxide, is expelled.

The Respiratory System.—In man the *organs* of *respiration* are classified for description as follows: (1) The respiratory passages, a system of cavities and tubes through which the atmospheric air gains access to the lungs and through which the impure air is expelled. (2) The lungs, where the interchange of gases of the air and blood takes place. (3) The thorax, which by its expansion fills the lungs with a fresh supply of air and which by its relaxation aids in the expulsion of the impure air. (The latter function is effected principally through the collapse of the lungs by virtue of their elasticity.) (4) Nervous structures, which control the rate and depth of respiration.

Air may pass into the respiratory passages by way of the nose or mouth. Of these two the *nasal passages* are especially adapted for breathing, for the cavity of the nose is lined with mucous membrane richly supplied with bloodvessels which aid in warming the inspired air; furthermore, this membrane is thrown into intricate folds so that much of the dust and other impurities of the air which would otherwise enter the respiratory passages do not pass beyond the nasal cavity. The mouth and nose communicate with the pharynx and the latter with the larynx.

The *larynx* is a cartilaginous box, triangular on cross-section above and circular below where it is continuous with the trachea. Like all the respiratory passages, it is lined with mucous membrane. In the triangular portion of the larynx, the *vocal cords* are situated. These structures are bands of elastic tissue, lying directly under the mucous membrane, which by their vibration, under the influence of a blast of air, produce sounds known as the voice.

At the upper extremity of the larynx and lying just behind the tongue is a leaf-shaped structure, the *epiglottis*, consisting of cartilages. Although not directly associated with the respiratory act, the epiglottis is of great importance, as by its lid-like action it closes the larynx during swallowing and thus prevents the passage of food into the respiratory tract.

The *trachea* is continuous above with the larynx. The mucous membrane of this tube and its subdivisions is of special interest, as the uppermost layer of this membrane consists of *ciliated cells*. These cells are furnished with cilia, or hair-like processes which by their motility sweep dust particles toward the external world and thus prevent their entrance into the lungs.

The subdivisions of the trachea, the *bronchi* and *bronchioles*, are generally included with the lungs. The two bronchi, into which the trachea divides, enter the right and left lungs respectively, where they subdivide into numerous smaller tubes known as the bronchioles. (The bronchi and the larger bronchioles are similar to the trachea in structure, but the smaller bronchioles, those which terminate in the air chambers of the lungs, have much thinner walls and are not supplied with cartilaginous rings.) The bronchioles further subdivide and finally terminate in dilated cavities, the *infundibula*. The walls of each infundibulum are closely beset with still smaller chambers, the alveoli, where the actual exchange of gases takes place. The alveoli consist of a single layer of flat cells supported by delicate elastic tissue under which lie a close network of capillaries (small bloodvessels).[1]

The *lungs* therefore consist of myriads of these air chambers, furnished with passages (bronchioles and bronchi) leading to the external air.

The lungs are enclosed in a conical shaped, air-tight chamber known as the *thorax*. Each lung is tucked into a sac, the *pleura*, one layer of which invests the surface of the lung, the other being attached to the inner surface of the thorax. This sac is lined with a single layer of flat cells which secrete a thin fluid. The purpose of this secretion is to reduce the friction between the lungs and the thorax during respiration.

The *bones of the thorax* are the sternum in front, the twelve ribs on each side and the thoracic vertebræ behind. Owing to the convexity of the ribs and the peculiar manner in which they articulate with the vertebræ, the capacity of the chest is greatly increased when the ribs are elevated by the contraction of muscles during inspiration. Running obliquely between the adjacent ribs are two sets of muscles, the *internal and external intercostals*. The base of the thorax is shut off from the abdominal cavity by the *diaphragm*, a dome-shaped muscle with its convexity upward. The structures at the root of the neck complete the thorax above.

The muscles concerned in respiration are activated by impulses transmitted through *nerves*, which in turn are controlled by a central station known as the *respiratory center*.

The respiratory center is composed of nerve cells situated in the *medulla* (a portion of the central nervous system lying between the upper part of the spinal cord and the brain). These cells are surrounded by bloodvessels and react to changes in the gaseous contents of the blood, being especially susceptible to increases in carbon dioxide.

[1] It will be noted that the air contained in the alveoli is separated from the circulating blood, by only two layers of flat cells, one layer forming the wall of the alveolus, the other the wall of the capillary. Through this double membrane oxygen and carbon dioxide can diffuse with great facility.

The Mechanics of Respiration.—During *inspiration* the muscles of the thorax contract under the influence of impulses sent through nerves from the respiratory center.

The *intercostal muscles* (the external and internal) by their contraction lift the ribs and increase the lateral and anteroposterior diameters of the chest. At the same time the *diaphragm* contracts and thus becomes flatter, its central portion moving downward, so that by the simultaneous contraction of these muscles the capacity of the thorax is increased in all dimensions.

This enlargement of the thorax must be followed by an expansion of the lungs as the pressure exerted through the respiratory passages (atmospheric pressure) upon the interior of the alveoli is always greater than the counter-pressure exerted by the elasticity of the lungs. As the lungs expand the pressure in the alveoli necessarily becomes less than that of the external air so that the latter rushes into the alveoli until an equilibrium is established. It is during this phase, known as inspiration, that a fresh supply of oxygen is brought in contact with the blood circulating in the lung.

The lung tissue is also supplied with nerves and the expansion of the lungs gives rise to nervous impulses, which reaching the respiratory center, arrest the impulses to the respiratory muscles, so that the latter relax. With this relaxation *expiration* sets in. The ribs are brought back to their position of rest by gravitation and by virtue of the elasticity of the thoracic cage. Furthermore, the return to the expiratory position is aided by the traction exerted upon the chest walls by the elasticity of the lungs.

As the capacity of the thorax and consequently the volume of the lungs diminish the pressure in the alveoli becomes greater than that of the external air, so that the lung air, deficient in oxygen and rich in carbon dioxide, is expelled through the respiratory passages.

Changes in the Air.—*Atmospheric air* contains 21 per cent. of oxygen, 79 per cent. of nitrogen and a small fraction of carbon dioxide (3 parts in 10,000). The *expired air*, on the other hand, contains about 17 per cent. of oxygen, 79 per cent. of nitrogen and 4 per cent. of carbon dioxide. This, of course, indicates that during respiration about 4 per cent. of oxygen is absorbed by the blood and 4 per cent. of carbon dioxide excreted from the blood into the alveoli. The nitrogen percentage remains the same, for it behaves as a neutral gas and is not absorbed in the lungs. It should also be mentioned that the blood in passing through the lungs gives off a small amount of its water, about one pint being excreted daily.

The *rate and depth of respiration* vary with the age and the degree of activity in the individual. In the adult the *normal rate* during rest is about 16 to 20 per minute and the amount of air taken in each inspiration is about 1 pint. Both the rate and depth of respiration increase markedly during exercise, the total capacity of the lungs under forced breathing being about seven pints.

Nervous Mechanism.—At first sight the respiratory act appears to be under control of the will, but this is true only to a slight degree. Respiration is actually an *involuntary function* under the constant regulation of the respiratory center. As has been seen, the irritability of this center is influenced by the carbon dioxide contents of the blood. *During exercise* when the activity of the muscles gives rise to an increase of carbon dioxide in the circulating blood, the *respiratory center*, which is sensitive to slight changes of carbon dioxide, is *stimulated* to greater activity. This stimulation of the center is followed by a corresponding increase of activity in the respiratory muscles, so that respiration during exercise is deeper and more rapid. Conversely, during sleep less carbon dioxide is formed in the tissues, the respiratory center is not so strongly stimulated and consequently respiration is considerably slower.

There is, therefore, in the respiratory function, not only a means of supplying the tissues with oxygen and removing carbon dioxide, but also an automatic mechanism whereby the supply and removal is controlled according to the constantly changing requirements of the body.

PHYSIOLOGY OF THE CIRCULATION.

The Circulatory System.—The *circulatory organs* consist essentially of a closed, continuous system of tubes through which blood, the common nutritive fluid of the body, is kept in constant circulation by the pump-like action of the heart.

The circulating blood serves *two purposes:* to convey food and oxygen to the body cells and to carry to the organs of excretion the waste products resulting from cellular activity.

The Blood.—The blood is a red, opaque fluid and makes up about one-thirteenth of the body weight. On microscopic examination this fluid is found to consist of several varieties of cells suspended in a clear yellowish fluid known as *plasma*.

The *cellular elements* of the blood are of three types: the red blood cells or erythrocytes, the white blood cells or leukocytes and the blood platelets.

The *red blood cells* are thin, biconcave, non-nucleated, circular disks, about one thirty-five hundredths of an inch in diameter. These cells are composed of protoplasm in which is found an iron-containing substance called *hemoglobin*. It is to this substance that the red color of the blood is due. Hemoglobin has a great affinity for oxygen, and owing to this property the red blood cells are able to absorb oxygen during their passage through the lungs.

The *white blood cells* or *leukocytes*, less numerous and somewhat larger than the red blood cells, are more or less irregular in shape, colorless, and have a well-defined nucleus. By a form of motility similar to that of the ameba (ameboid motion) these cells are able to engulf foreign particles. This function, known as *phagocytosis*, is especially important in disease, the invading germs being destroyed in great numbers by the leukocytes. Another property of the white blood cells is the production of a ferment which assists in the clotting of blood.

The *blood platelets* are very small cells probably concerned only with the process of clotting.

The fluid portion of the blood or *plasma* is a yellowish, alkaline fluid consisting of 90 parts of water holding in solution albumin, sugar, mineral salts, and other substances which are constantly replenished by the intake of food. The plasma therefore represents the nutritive element of the blood from which the cells derive their needs. Owing to the alkalinity of the plasma, carbon dioxide is readily dissolved in this fluid, and in this manner is carried from the cells to the lungs where this gas is excreted. The plasma also acts as a solvent for other excretory products of the cells which can be then conveyed to the excretory organs and there finally expelled from the body.

The blood when removed from the body is soon transformed into a semisolid mass. This transformation, known as coagulation or *clotting,* takes place through the agency of a ferment derived from the blood platelets and leukocytes.

This ferment precipitates part of the albumin of the plasma in the form of delicate fibrils which form an interlacing network. In this network the cellular elements become entangled, the whole mass forming the clot. The purpose of coagulation is to prevent the excessive loss of blood after injury to the tissues, the coagulated mass occluding the mouths of the bleeding vessels.

The blood is kept in constant circulation throughout the body by the pumping action of the heart.

The Heart.—The heart is a hollow muscular organ, conical in shape. It is situated in the thorax, lying between the two lungs just above the diaphragm and behind the breast-bone or sternum. It is placed obliquely so that its *apex* reaches to a point just inside and a little below the left nipple. The heart is surrounded by the *pericardium,* a connective-tissue pouch made up of two layers, one of which is closely adherent to the heart wall, the other being attached to the surrounding structures. The interior of this pouch is lined with a single layer of flat cells which secrete a thin fluid. This fluid serves to diminish the friction between the heart and the adjacent organs.

The *interior of the heart* is divided by a longitudinal muscular wall into two distinct cavities, each of these cavities being subdivided by valves into two compartments, a lower and an upper, which communicate with each other. The heart is thus divided into four chambers. The two upper chambers are called the right and left *auricles,* the two lower, the right and left *ventricles.* The outlets of these chambers are guarded by *valves* which prevent the back flow of blood after its expulsion from any one chamber and keeps the blood circulating in the same direction.

The *heart walls* consist of muscle cells, roughly columnar in shape and striated. These cells have the peculiar property of contracting and relaxing at fairly definite intervals. This rythmical action gives rise to the heart beat. The muscular walls of the different chambers of the heart vary in thickness, according to the amount of work performed by these parts. The walls of the auricles are thin as the pressure in these chambers is always comparatively low; the walls of the left ventricle, on the other hand, are very thick, as it must propel the blood against the high pressure in the systemic vessels. The right ventricular walls are thinner than the left, as the pressure in the lung vessels, into which the right ventricle pumps its contents, is much lower than the pressure in the systemic vessels. The *internal surface* of the the heart is lined with a single layer of cells, this layer is continuous throughout the whole circulatory system and reduces friction by offering a smooth surface to the rapidly flowing blood. The movements of the heart consist of the alternate contraction and relaxation of the heart walls. Each *heart beat* is divided into three stages: (1) The contraction of the auricles; this is rapidly followed by (2) the contraction of the ventricles during which the auricles relax; and (3) a pause during which both auricles and ventricles are relaxed.

The heart is so designed that two streams of blood are pumped simultaneously. The *right side* of the heart receives the blood on its return from the tissues and pumps it into the lung vessels where a fresh supply of oxygen is absorbed and carbon dioxide given off. The *left side* of the heart receives the blood after its transit through the lungs and discharges the now aerated blood into the systemic vessels to be distributed throughout the body.

The Bloodvessels.—The tubes or vessels through which the blood circulates are divided according to their structure and function into arteries, arterioles, capillaries, venules, and veins.

The *arteries*, vessels which conduct the blood away from the heart, are made up of three layers, an internal layer of flat cells, a middle muscular layer containing numerous elastic fibers and an outer layer of tough connective tissue. To this structure the arteries owe their great elasticity and strength. Strength is essential to resist the great pressure in these vessels, and the elasticity permits the arteries to distend at each heart beat and thus to accommodate the three or four ounces of blood suddenly expelled into their lumen by the contraction of the ventricles. The arteries branch repeatedly, each successive division giving rise to smaller and smaller vessels until the *arterioles* are reached. The latter differ from the arteries in that their external and middle layers are much thinner and contain very little elastic tissue. These vessels, being under control of the nervous system, are able to contract or dilate under stimulation. By this mechanism the amount of blood circulating through any organ is regulated.

The arterioles subdivide like the arteries and terminate in minute vessels known as *capillaries*. The capillaries, consisting only of a single layer of flat cells, form a network of microscopic tubes the meshes of which are occupied by the cells. Owing to the thinness of the capillary walls, *plasma* diffuses readily into the spaces of this capillary network and in this way the albumin, sugar, and other foods contained in the plasma are brought into immediate contact with each cell of the body. *Oxygen* diffuses likewise from the red blood cells into the intercapillary spaces where it is absorbed by cells. The *carbon dioxide* and *other excretory products* of the cells passing in the opposite direction, enter the blood through the capillary walls and are carried away by the circulation to be excreted from the body.

The network of capillaries formed by the division of each arteriole unite again to form vessels known as *venules;* the later in turn join to form larger vessels, called *veins,* which return the blood to the heart. The veins, like the arteries, are composed of three coats. In the veins, however, the outer coats are much thinner, as the pressure in the veins is considerably lower than that in the arteries. The veins are furnished with *valves* which permit the passage of blood only in the direction of the heart.

As has been seen, the heart is composed of two distinct halves—the right side of the heart pumping blood into the lungs, the left side forcing blood throughout the body. There are therefore two systems of bloodvessels, one between the right ventricle and left auricle, the other between the left ventricle and the right auricle. The first is known as the *pulmonary circulation,* the second as the *systemic circulation.*

The Pulmonary Circulation.—The blood returning to the heart after its circulation through the tissues, enters the *right auricle* through two large veins, the inferior and superior vena cava. It then passes into the relaxed *right ventricle.* The right auricle contracts and thus completes the filling of the ventricle. The auricles now relax and the ventricles contract. As the pressure in this chamber increases, the blood pressing against the under surface of the *tricuspid valve* (between right auricle and ventricle) brings about its closure.

When the pressure in the right ventricle exceeds that in the pulmonary artery, the *semilunar valve,* situated at the outlet of the ventricle, opens so that the blood is forced into this vessel. After ventricular contraction has reached its height relaxation commences, and the pressure in the pulmonary artery closes the semilunar valve. The *pulmonary artery* divides into branches which enter the substance of the lungs. Within the lungs, these branches subdivide into arterioles and the latter into capillaries which form a network about the respiratory chambers (alveoli).

The blood during its passage through the lung capillaries throws off carbon dioxide and absorbs a fresh supply of oxygen. The lung capillaries empty into venules, the venules unite to form veins which finally empty the oxygenated blood into the left auricle by way of four large vessels, the *pulmonary veins.*

The Systemic Circulation.—The blood returning from the lungs passes from the *left auricle* into the *left ventricle,* the filling of this chamber is aided by the contraction of the auricle. The left ventricle then contracts, and the auricle relaxes. The rising pressure in the ventricle closes the *mitral valve* (between the left auricle and ventricle), and opens the *aortic semilunar valve,* so that the contents of the ventricle are forced into the *aorta,* a large artery which through its branches carries the aerated blood to all parts of the body. As the ventricle relaxes the pressure in the aorta closes the aortic valve. The blood passes successively through arteries, arterioles and capillaries. In the capillaries the oxygen and food is distributed to the cells and carbon dioxide and other excretory products removed. The blood then passes from the capillaries into venules, next into veins, and finally returns to the right auricle by way of the two large veins, the *inferior* and *superior vena cava.*

The Portal Circulation.—Associated with the organs of alimentation and of special importance during digestion is a third system of vessels known as the *portal circulation.* The veins of the abdominal alimentary organs do not pass directly into the vena cava but unite to form a large vessel, the *portal vein,* which enters the liver. In the *liver* the portal vein subdivides into capillaries which form a close network about the liver cells. From this capillary network arise veins, which unite to form the *hepatic vein,* which in turn empties into the inferior vena cava. The alimentary organs receive their blood supply from branches of the aorta. In the mucous membrane of the stomach and intestines these branches subdivide in capillaries. Here the capillaries serve a twofold purpose, they carry aerated blood to the cells of these organs, and during digestion convey the absorbed peptones and sugars to the liver by way of the portal vein. In the liver the capillaries arising from the portal vein bring these peptones and sugars in close contact with the liver cells. The excess of *sugar* is converted into glycogen which is stored in the liver for future use and the *peptones* are modified and carried away in the blood plasma to be distributed to all cells of the body.

The Lymphatic System.—Related to the circulation of the blood is another system of vessels known as *lymphatics.* The lymphatics begin as exceedingly minute vessels which arise from the spaces between the cells. These *intercellular spaces* contain fluid derived from the plasma of the blood which has diffused through the capillary walls. The small lymphatics, therefore, drain off this fluid after the food originally contained in it has been absorbed by the cells. The excretory products are not entirely removed by the blood so that the fluid carried away by the lymphatics contains part of the excretions of the cells. The lymphatics unite to form large vessels which empty at intervals into the *lymphatic glands.* In these glands white blood corpuscles are formed and are eventually carried into the blood stream by the lymphatic channels. From the lymphatic glands the lymph passes into larger vessels which unite to form the *right* and *left thoracic ducts.*

The *right thoracic duct* is a short vessel which drains the lymph from the right side of the head, the right arm and the corresponding half of the thorax. It empties into veins situated at the root of the neck.

The *left thoracic duct* is a long vessel which drains the remaining lymphatics of the body including those of the intestines. The lymph capillaries in the villi of the small intestines are concerned principally with the *absorption of fats* during digestion. The absorbed fats are thus thrown directly into the blood stream by way of the left thoracic duct which also empties in veins at the root of the neck.

The lymphatic vessels, like the veins, are supplied with valves which allow the lymph to flow only in the direction described.

PHYSIOLOGY OF EXCRETION.

The maintenance of health in any organism depends upon the constant removal of the excretory products arising from the metabolism of its cells.

The most important *excretory products* are carbon dioxide, urea, uric acid, sulphates, phosphates, chlorides, and water.

Carbon dioxide, as we have seen, results principally from oxidative processes in the cells.

Urea and *uric acid* are the final products in the breaking down of protoplasmic material and represent not only cellular wastes, but also the decomposition of protein foodstuffs after their absorption from the alimentary tract.

The *sulphates, phosphates, chlorides,* and *water* are derived partly from cellular changes, and partly from the amount of these substances absorbed during digestion in excess of the needs of the cells.

These products, constantly excreted into the blood and lymph, are conveyed by the circulation to the excretory organs where means are provided for their removal.

Excretory Organs.—The organs concerned in the removal of these products are the lungs, the skin, and the kidneys, accordingly they are known as the *organs of excretion.*

The *lungs,* the function of which has already been considered, excrete practically all the carbon dioxide formed in the body and in addition about a pint of water daily.

The *skin,* besides its excretory function, plays other important parts in the economy of the body.

The skin is divided into an external layer, the *epidermis,* or scarf skin, and an internal layer, the dermis, or *true skin.* The epidermis consists of numerous superimposed cells, the uppermost of which are dead, and constantly dropping off. The cells thus lost are replaced by the multiplication of cells at the bottom of this layer. The epidermis has no bloodvessels and derives its nourishment from the lymph which escapes through the walls of capillaries in the true skin, and this accounts for the death of the externally situated cells which are unable to obtain a sufficient supply of food. The *function* of the epidermis is a protective one. It covers the entire surface of the body, and by its horny texture prevents injury to the underlying tissues.

The internal layer of the skin or *dermis*, upon which the epidermis lies, is made up of numerous interlaced connective-tissue fibers richly supplied with bloodvessels and nerves. The dermis at its point of contact with the epidermis is studded with *papillæ,* minute finger-like elevations, which contain loops of capillary vessels. Many of the papillæ contain in addition *sensory end-organs* through which external impressions are received. The function of the skin as a sensory organ will be again mentioned under the nervous system.

Two important sets of structures situated in the dermis are the *sebaceous* and *sweat glands.*

The *sebaceous glands* consist of minute sacs lined with a single layer of cells, each sac emptying into a common channel which opens into a hair follicle. The cells of these glands have the property of manufacturing, from substances derived from the blood, an oily secretion which passes to the skin surface through the hair follicles. The *purpose of this secretion* is to keep the skin soft and pliant and prevent the drying of the hair.

The *sweat glands* are composed of a single tube also lined with a single layer of cells. This tube is coiled several times upon itself and opens externally by a straight duct which passes through the epidermis. The openings of these ducts are called *pores.* The coiled portion of the gland is surrounded by a network of capillaries, so that the blood is brought in close contact with the gland cells. The latter by their selective action remove certain materials from the blood which are then excreted through the pores. This *excretion*, known as sweat, consists of water, carrying in solution salts and a small amount of urea, carbon dioxide, and fatty acids. To the latter the peculiar odor of this excretion is due.

The arterioles of the dermis, in conjunction with the excretion of sweat, play an important part in the *heat regulation* of the body. During exercise when an enormous amount of heat is generated by the activity of the muscle cells, the bloodvessels of the skin dilate and the secretion of sweat increases. The dilatation of the skin vessels brings the overheated blood to the surface in great quantities, where it loses heat by radiation, the external air being cooler than the blood. The sweat, on the other hand, evaporates rapidly and in this way causes a marked loss of heat.

If the skin is exposed to cold the reverse occurs, the bloodvessels of the skin become constricted and the secretion of sweat diminishes. In this way heat loss is prevented.

The *kidneys* are, with the lungs, the most important organs of excretion. The lungs are concerned principally with the excretion of carbon dioxide and the kidneys with the greater part of the solid excretory products as only a small portion of these products are excreted through the skin.

The *urine,* the fluid resulting from the activity of the kidneys, consists of an aqueous solution of urea, uric acid, phosphates, sulphates, chlorides, a very small quantity of carbon dioxide and pigment. To the latter the characteristic color of the urine is due.

The kidneys, two in number, are situated in the upper part of the abdominal cavity on either side of the spinal column. These organs are bean-shaped with their concavity facing the spine.

From the stand-point of function the *essential parts of the kidney* are: (1) The tubules, the cells of which by their selective action remove solid excretory products and water from the blood. (2) The bloodvessels which convey the blood to the tubules. (3) The pelvis of the kidney into which the tubules empty their contents.

The tubules of the kidneys with their related bloodvessels form little systems, which are exceedingly numerous, but as these systems are all alike in structure and function, the description of a single one will suffice.

The *tubules,* little tubes consisting of a single layer of cells, begin as minute blind pouches near the external surface of the kidney. These pouches may be compared to the inverted tip of the finger of a glove. The blind extremity of the tubules is thus composed of two layers of flat cells, an internal layer forming a dilated cavity and an external layer continuous below with the walls of the tubules. Into this dilated cavity an arteriole enters which immediately divides into a network of capillaries. This portion of the tubule with its capillary tuft is called a *Malpighian corpuscle.* Soon after leaving its blind, pouched extremity, the tubule, from now on lined with a single layer of cubical cells, is coiled spirally for a few turns (proximal convolution) and then dips down in a straight line for a short distance toward the concavity of the kidney; it then bends back upon itself and returns to a position near its point of origin, where it forms a second series of coils (the distal convolution). Both the first and second coils of the tubule are surrounded by networks of capillaries.

The tubule after leaving the distal convolution enters collecting tubules, which, joining with tubules of other similar systems, run in a straight course toward the concavity of the kidney and empty by small openings into the pelvis of this organ.

The *secretion of urine* takes place in the following manner. The blood which contains the excretory products reaches the kidney by way of the renal artery, a branch of the aorta. The renal artery subdivides into branches, which on entering the concave side of the kidney, divide into numerous arterioles. These arterioles pass between the collecting tubules and near the external surface of the kidney give off branches which enter the blind pouches formed by the infolding of the extremities of the tubules (the Malpighian corpuscle). Each pouch receives an arteriole which divides into a tuft of capillaries. At this point a process of selective filtration takes place. The *water* and *salts* to be excreted from the blood filter through the capillary walls and then through the single layer of cells forming the wall of the tubule and thus collect in the interior of the latter.

From the capillary tuft just described a small vein arises which carries the blood along to the *proximal* and *distal convolutions* of the urinary tubules. There the vein again divides into a second network of capillaries. The cells of the tubules at this point have the *power of selecting* certain substances from the blood, such as urea and uric acid, and at the same time of reabsorbing the excess of the water which has passed into the tubule from the first system of capillaries.

The blood, now relieved of excretory products, is collected by veins which, joining with other similar vessels, empty into the renal vein, a tributary of the inferior vena cava.

The urine after its passage through the course of the tubules enters the pelvis of the kidney. From this dilated sac the urine passes through the ureter into the bladder, where it collects until voided by the act of micturition.

PHYSIOLOGY OF THE NERVOUS SYSTEM.

The *function* of the nervous system is purely correlative. Through the activity of its units, the nerve cells, it brings organs into intimate relation and thus harmonizes their vital processes, and through receptive organs, those of the special senses, it relates the body as a whole to its external surroundings.

The Nerve Cell.—The *functional unit* of the nervous system is the nerve cell or neuron. The *neuron* consists of a nucleated cell body from which issue two or more protoplasmic processes, the nerve fibers.

When a nerve cell is stimulated either by chemical or physical causes, a current arises which is known as a *nervous impulse*. This impulse, which may be aroused from changes at the periphery of the fiber or in the nerve cell body, is transmitted by the nerve fiber in a way comparable to a current of electricity travelling through a wire.

Nerve Fibers.—The nervous impulse in its course through the nerve fiber, always travels in a definite direction, accordingly all neurons are divided into three large classes: (1) The *afferent neurons*, the fibers of which convey impulses from all parts of the body *to* central stations in the nervous system. (2) The *efferent neurons* which conduct impulses *from* these central stations to the cells of all the organs. (3) The neurons which transmit impulses from *one nerve cell to the other*.

Receptive Organs.—The afferent nerves are supplied at their point of origin with specialized structures known as *receptive organs*. These receptors are part of the nerve fiber and are adapted to receive impressions arising from changes in the surroundings of the organisms or from changes in its tissues. These receptive organs and the afferent nerves to which they are attached are specialized in function and so respond best to one particular form of stimulation.

To illustrate: The receptive organs of the skin receive impressions of pain, heat, cold, touch, and pressure. When an object is brought in contact with the skin, the receptive organs of touch are stimulated. They originate an impulse which is conducted through the fiber to the central nervous system where our consciousness translates this impulse into the sensation of touch.

If the skin is pricked with a pin, receptive organs of pain are stimulated and a sensation of pain is aroused. In this way the organism is acquainted with immediate external changes and can respond accordingly.

Situated in the joints, tendons, and muscles are receptive organs which give us what is known as the *muscle sense.* This sense enables us even with our eyes closed, to determine the exact position assumed by our limbs, trunk, and head.

The receptive organs of *sight* are located in the retina of the eye. Light waves entering through the pupil stimulate afferent nerves, the impulse is conveyed to the brain and gives rise to the perception of color and shape.

In the upper part of the nasal cavity, lying in the mucous membrane are the receptive organs of *smell.* Volatile substances coming in contact with these endings, give rise to olfactory sensations.

The internal ear contains two sets of receptive organs, one sensitive to air vibrations and through which we perceive *sound,* the other transmitting the impulses which regulate the *equilibrium* of the body.

The sense of *taste* arises from the stimulation of endings in the mucous membranes at the posterior part of the tongue.

All the internal organs are also supplied with afferent fibers which conduct impulses centrally.

The *efferent nerve fibers* which convey impulses peripherally to the cells of the body are divided into three classes: (1) The *motor nerves.* (2) The *secretory nerves.* (3) The *inhibitory nerves.*

The *motor nerves* carry impulses to the muscle cells and thus bring about their contraction. The voluntary muscles are supplied by motor neurons arising from the central nervous system. The smooth muscles of the bloodvessels and the internal organs are supplied by motor fibers from the sympathetic system.

The *secretory nerves* are derived from the sympathetic system and terminate in gland cells throughout the body. It is the stimulation of such nerves that activates the flow of secretions, *i. e.,* the saliva, the gastric juice, etc.

The *inhibitory nerves,* also branches of the sympathetic system, supply the muscle cells of the heart and bloodvessels. Their function is to suppress or diminish the activity of these structures. Examples of these are the vagus nerve, which slows the heart rate, and the vasodilator nerves, which bring about the relaxation of bloodvessels.

In the central and sympathetic nervous system the afferent and efferent nerves are brought into relation with each other in such a way that any afferent impulse arising from the periphery is always followed by a suitable efferent response.

The Central Nervous System.—The central nervous system includes from below upward, the spinal cord, the medulla, the cerebellum, and the cerebrum.

The *spinal cord* presents on cross-section a butterfly-shaped area, grayish in color, and made up of numerous nerve-cell bodies and their fibers. Situated anteriorly in this gray matter are the cell bodies of the *spinal motor neurons*, the fibers of which supply the voluntary muscles. The gray matter is surrounded by bundles of nerve fibers (white matter) which run up and down the cord, their cell bodies lying at higher or lower levels.

From the anterior portion of the cord at the level of each vertebra two large nerve trunks arise, one on either side. These trunks are known as the *anterior roots* and contain the fibers of the *spinal motor neurons*.

From the posterior aspect of the cord and at corresponding levels arise similarly the *posterior roots*. These two trunks consist of afferent or *sensory fibers* which conduct impulses from the periphery to the spinal cord.

A short distance away from the spinal cord the anterior and posterior roots on each side *join* to form a single bundle, known as a *spinal nerve*. Just before joining with the anterior root, the posterior root presents an enlargement, the *spinal ganglion*, which contains the cell bodies of the afferent or sensory nerve fibers.

The *spinal nerves*, of which there are thirty-one pairs, pass out peripherally and by their subdivisions bring afferent and efferent fibers in contact with the tissues supplied by each spinal nerve.

Reflex Nervous Action.—The most primitive function of the nervous system is a *simple reflex action*. The simple reflex *involves only two neurons*, an afferent and an efferent. The path taken by the impulse is as follows: From the stimulation of a receptive organ an impulse arises which passes through the afferent neuron and enters the spinal cord through the *posterior root*. In the cord the afferent fiber subdivides into fibrils (terminal arborizations) which are in contact with *motor neurons*. The impulse passing through this point of contact is, so to speak, transferred to the motor neurons which pass out of the cord through the anterior roots and convey the impulse to the muscles they supply. The result is a muscular response not controlled by the will.

Reflex action always involves an afferent path, which may be represented by any afferent nerve, and efferent paths through motor, secretory or inhibitory nerves.

Not only in the spinal cord, but throughout the entire nervous system, we find reflex paths, some more complicated than others, through which important functions of the body are regulated. As an example of these regulative reflexes may be mentioned the profuse reflex flow of saliva and gastric juice which follows the stimulations of the nerves of taste.

The *white matter* of the spinal cord contains bundles of fibers which act as connecting paths between the peripheral afferent and efferent neurons and the *higher nerve centers* of the cerebrum and the cerebellum.

The Higher Motor Paths.—Among these higher nerve centers are the *voluntary motor neurons* which are situated in the *cortex or gray matter* of the cerebrum, on its lateral aspect. In this area arise motor impulses originated by the will. The fibers of these neurons pass into the medulla (the first part of the cord) where the greater part of them cross over to the opposite side from which they originated, and then, passing on through the medulla, run down the spinal cord. At different levels individual fibers leave this motor bundle or tract as it is called and by their terminations come in contact with the spinal motor neurons of corresponding levels.

Owing to the crossing of the fibers in the medulla, each half of the brain controls *voluntary motion* on the opposite side of the body. Therefore when a part of the body is voluntarily moved as, for example, the left index finger, the impulse arises in the brain cortex on the right side and travels to the medulla where it crosses to the left side; it then continues its course down the spinal cord and at the level of the arms passes over to the spinal motor neurons which then convey the impulse to the muscles concerned in moving the part.

The Higher Sensory Paths.—Thus far only the peripheral afferent neuron has been considered and the part it plays in reflex activity. But as the ability to perceive sensations resides in the brain, pathways are required to transmit impulses from these afferent nerves to this organ.

The *sensory nerve fibers* after their entrance into the cord, divide into *two parts: one,* as already mentioned, comes in contact with adjoining motor neurons; the *other* ascends the posterior portion of the spinal cord and ends in the medulla. At this point are located other cell bodies which through their fibers complete the path to the brain. These fibers, like the motor fibers, cross to the opposite side and end in the cortex just behind the cell bodies of the voluntary motor neurons.

The Cerebellum.—The spinal cord contains other nerve paths which relate afferent and efferent nerves with the *cerebellum,* and this organ is in turn related to the cerebrum by nerve paths. The *function of the cerebellum* is to coördinate muscular movement.

The Medulla.—The medulla is the continuation of the upper part of the spinal cord and gives origin to some of the cranial nerves. Through it course the afferent and efferent nerve paths which bring into relation the spinal cord with the cerebrum and cerebellum. The medulla is of great importance, for it is the seat of nerve centers which control the *vital functions*. In it are located the respiratory, the cardiac and the vasomotor centers.

The *respiratory center* contains cell bodies the fibers of which run down the spinal cord where they communicate with the motor neurons supplying the muscles involved in the respiratory act. The function of this center has been considered under Respiration.

The *cardiac centers* regulate the heart rate through two important nerves, the *vagus* and the *accelerator*. The vagus decreases the heart rate and the accelerator increases it.

The *vasomotor center* contains cell bodies which carry impulses to the muscle of the bloodvessel walls through the vasoconstrictor and vasodilator nerves. The former constrict the bloodvessels, thus raising the blood-pressure, while the latter have exactly the opposite effect and lower blood-pressure.

The Cerebrum.—The *cerebrum* is composed of gray and white matter. The *gray matter*, made up of numerous cell bodies and their fibers, is distributed into two groups, the cortex and the basal ganglia.

The *cortex*, the surface of which is greatly increased by numerous folds or convolutions, is divided into three functional areas: the motor, the sensory and the higher psychic.

The *motor areas* control voluntary motor activity.

The *sensory areas* are located in various regions of the cortex, each area receiving the final nervous paths of one particular special-sense organ.

All these regions of the cortex are in turn intimately related by nervous connections with the *psychic areas* from which the higher mental processes originate.

The *basal ganglia* are series of nerve cell masses, at the base of the brain.

The *white matter* consists of the motor and sensory paths already mentioned and nerve fibers connecting the different areas of the brain.

The Sympathetic Nervous System.—This system consists of ganglia and numerous communicating and distributing nerve fibers.

The *ganglia* form two principal groups, (*a*) those of the ganglionated cord on either side of the spinal column, and (*b*) the more peripherally situated ganglia of the plexuses of the thoracic, abdominal, and pelvic cavities. Collections of sympathetic neurons are also found in the wall of the visceral organs, *i. e.*, the heart, intestines, etc.

The *important efferent branches* of the sympathetic system are the following. The *pupil-dilating* fibers which bring about the dilatation of the pupil; the *vasomotor nerves* (vasoconstrictors and dilators) controlled by the vasomotor center in the medulla; the *motor fibers* to the smooth muscle cells of the alimentary tract; the *secretory nerves* supplying all the gland cells of the body; and the *nerves regulating the rate* of the heart.

The *afferent* sympathetic nerves convey impulses from the visceral organs to reflex centers in the central nervous system.

CHAPTER IV.

BACTERIOLOGY AND STERILIZATION.

By L. F. RETTGER, Ph.D.

For many years it was thought that insofar as the body was concerned bacteria were necessary to its welfare; that they helped it in some way. It was even thought, by many at least, that life was maintained by the very existence of bacteria within the body.

For example, it was taught that some of the intestinal bacteria were necessary for certain processes that go on in the intestine; that intestinal digestion was not complete without bacteria. The problem was argued pro and con for years but it has been well demonstrated that the old view was an erroneous one.

Yet, while the bacteria that are present in the body are not necessarily helpful, there are organisms in nature which do aid in an economic way, such as those which are of special importance in connection with the growing of plants. Some farm products depend in a large measure on bacteria. So that, in spite of what is said as to the probability that bacteria are useless within the body, we owe much to them because of this external coöperation.

Ordinarily the bacteria within the body are harmless. Normally they are unable to overcome its natural resistance. Fortunately it is against only a few kinds of bacteria that the body is compelled constantly to protect itself. The fight against these of course constitutes one phase of hygiene and a most interesting and important one.

The practice of this phase of hygiene falls within the modern conception of medicine; to prevent bacteria or other harmful agencies from getting a foothold and working mischief, rather than to try to eliminate them after they once establish themselves should be the chief aim of science. A few years ago ex-president Eliot of Harvard said that the real medical school of the future was the school of preventive medicine. Modern dentistry, like medical science, is likewise moving in that direction. This is due to the fact that men who are active in the practice of these professions now realize that they will accomplish the greatest good if they direct their energies toward the prevention rather than the cure of disease.

There are many diseases that are now known to be caused by bacteria, such as typhoid fever, tuberculosis, diphtheria, and a large number of others, the specific causes of which are well recognized. Combating typhoid fever means, in reality, keeping out of the way of the bacterium which causes it. In the present-day fight against

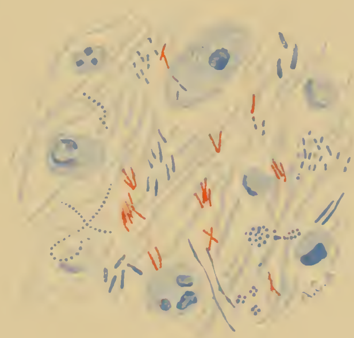


Fig. 42.—Tuberculous sputum stained by Gabbett's method. Tubercle bacteria seen as red rods; all else is stained blue. (Abbott.)

tuberculosis an endeavor is made to keep out of the way of the tubercle bacillus. Since there are so many chances of getting into trouble with foreign harmful agencies like bacteria, it is important to know something about them.

Description of Bacteria.—Some of the largest bacteria measure $\frac{1}{25000}$ of an inch in thickness, or, in other words, it takes 25,000 of them packed closely side by side to cover an inch. This gives a vague conception of the minuteness of these organisms. In order that they may be examined it is necessary to use the best and most powerful microscope to bring them to view. From this it can readily be understood that years of scientific study have been required to glean any real knowledge concerning them.

Bacteria are *vegetable organisms*, not animal. Therefore it is wrong to call them bugs, worms, or anything inferring a close relationship to that kingdom.

A bacterium is essentially a minute mass of protoplasm surrounded by a delicate envelope. This protoplasm is the same in bacteria as in all other living cells, and is peculiar to living matter.

Bacteria are *single-celled organisms.* They may often occur in bunches or chains, but their unit is the single cell; so that each individual bacterium is able to reproduce its kind.

CLASSIFICATION OF BACTERIA.

The protoplasm of the bacterial cells is held in shape by a delicate envelope, or defining wall; consequently bacteria can be regarded as being *definite* in *size* and in *shape.*

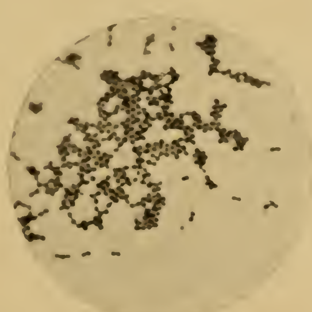


Fig. 43.—Staphylococcus. × 1100 diameters. (Park.)

In a large measure, the size, shape, internal structure and grouping of the different organisms are used as means of recognizing and classifying them. The tubercle bacillus is spoken of as being a *long, slender bacillus* (very long as compared with its thickness), and this fact is depended upon, to a large extent for diagnostic purposes, that is, for the detection of the tubercle bacillus in any part of the body that may possibly be infected with tuberculosis (Fig. 42). The same thing is true insofar as the typhoid bacillus is concerned. The common pus organisms that occur so frequently in the mouth, especially in abscesses of the gums and in abscesses in other parts of the body represent a different type. They are organisms which are *round* or *almost globular* (Fig. 43).

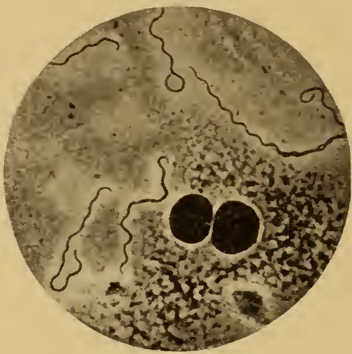


FIG. 44.—Spirillum obermeieri blood-smear. Fuchsin. × 1000 diameters. (From Itzerott and Niemann.)

There is a third type of organism which is often present in the mouth. It is also frequently found in stagnant water, and in infusions of hay, straw, etc. These are rod-shaped like the typhoid bacillus, but the rods are decidedly curved and longer; they resemble a *spiral* (Fig. 44).

We have then, first, the simple, straight, rod-shaped organism called the *bacillus* (Fig. 42); second, the globular type, known as *coccus,* or *micrococcus* (plural cocci, Fig. 43); and third, the long, slender, curved rod, known as the *spirillum* (Fig. 44, plural spirilla).

PROPAGATION OF BACTERIA.

How do these organisms propagate their own kind? In brief, bacteria multiply by a process of *transverse division.* A large bacillus, for example, when it has reached full maturity, divides into halves. The process is simply one of equatorial fission, or of separation of the halves by a little dividing wall which becomes more and more apparent until the constriction becomes complete, and instead of one parent cell two daughter cells appear. This is in reality the only method of multiplication. Spore formation, which is referred to later, does *not* constitute a state or stage of reproduction in the real sense of the word.

The above method is also spoken of as the *economic process* because of the great rapidity with which multiplication takes place. A bottle of milk will sour in the course of a few hours if kept at a moderately warm temperature. The milk spoils because it is such a good food for certain bacteria, known as the lactic acid organisms, that multiply rapidly.

Milk *sours*. Other foods, like meats, do not sour; they *decay*, and by an entirely different process; the decay of meat is ordinarily spoken of as *putrefaction*. But in either case the food is there, the bacteria are there, decomposition occurs, and in the process of this decomposition the bacteria have been multiplying rapidly.

It can be determined readily how rapidly these organisms reproduce themselves. Start with one organism, allow it to go on reproducing its kind at the rate of one reproduction an hour, that is, the doubling of the original bacillus and the doubling of each of its progeny once every hour, and there will be in twenty-four hours over 16,000,000 of them. If the reproduction occurs once in thirty minutes, it will be necessary to use higher mathematics to compute the number at the end of twenty-four hours, and frequently in a new medium like milk or beef broth which is prepared for such a purpose, reproduction does occur as often as once in thirty minutes. In some cases complete division may occur in twenty minutes. Thus it may be seen how the term *economic method* of multiplication applies.

Spore Formation.—There are many kinds of bacteria that have the property of being able to fortify themselves against destructive agents. This is accomplished by virtue of their ability to take on a form that is much more resistant to injury than the normal state of the organism. They can change themselves into what are termed *spores*. The tetanus or lockjaw bacillus has this property, for example. (Fig. 45.)

FIG. 45.—Tetanus bacilli with spores in distended ends. × 1100 diameters. (Park.)

A *spore* then is a transition form that certain bacteria can assume for purposes of defense.

Spores possess a thick wall, which is more or less impervious to heat, poisons, etc., and therefore protects the contents against fatal injury. In this way spore-producing organisms can fortify themselves against destructive influences which ordinary bacteria may be unable to resist. Spores remain dormant as long as conditions for growth and development are unfavorable. When, however, new food is supplied, and harmful influences have been removed, they develop into the original types of bacteria which gave rise to them by a simple process which may be called *germination.*

The *importance of the spore,* or spore-production by bacteria, cannot be overestimated. If it were not for the spore it would be very easy to sterilize objects. Fortunately, however, comparatively few disease-producing bacteria have the property of producing spores.

ARTIFICIAL CULTIVATION OF BACTERIA.

There are various ways of growing bacteria. Some favorable nutrient medium must be employed like milk, beef broth, and nutrient gelatin or jelly.

The examination of a specimen of milk or water is accomplished by putting a drop or several drops in a tube of jelly that has been warmed enough to liquefy it, mixing the contents well and then pouring it into little glass plates made for this purpose (Petri dishes). By this procedure it is possible to get the bacteria away from the milk or

Fig. 46.—Anthrax bacilli.

water and start them growing in the new medium. The jelly hardens just as ordinary table jelly does. After one, two or three days quite a change will have taken place in the jelly; the same sort of change that frequently takes place on a slice of bread that is put into the bread-box when damp; the same sort of change that takes place on a bit of cooked potato that is kept long enough. Families of bacteria have grown here and there, forming various sized masses. These families are the offspring of the individual bacteria that were in the drop of milk or water which was placed in the liquefied jelly. Such families or groups may frequently be distinguished from each other by their family traits. These families are known as *colonies.*

Frequently the microscope is used to examine the colonies as well as the individual organisms. As a rule each colony is the product of one original bacillus, spirillum, or micrococcus.

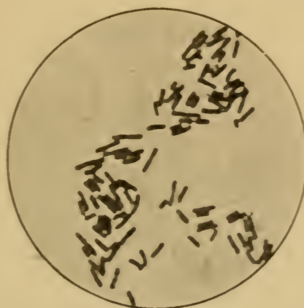


Fig. 47.—Typhoid bacilli from nutrient gelatin. × 1100 diameters. (Park.)

In studying a plate containing a number of colonies of different bacteria a great variation in their character will be noted. Some are large, others small; some are colored, others colorless, etc. In other words, they show different family traits. The differentiation of family characteristics plays an important part in the process of identification and is used for diagnostic purposes.

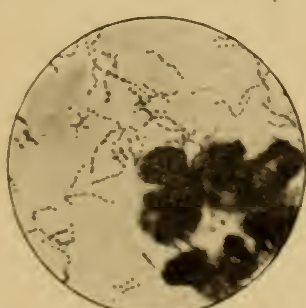


Fig. 48.—Streptococci in peritoneal fluid, partly enclosed in leukocytes. × 1000 diameters. (Park.)

Often the investigation is carried still further by various methods. For instance, one or more of these colonies may be further isolated; some of the individual bacteria may be removed from these colonies and placed in a tube of sterile jelly, milk or broth. The tube is then closed with an ordinary cotton plug, and put away for development. The organisms are now isolated or imprisoned, and may be held indefinitely under these conditions. Why is all this necessary? Just as soon as one bacterium is isolated from another and studied, the danger of confusion is avoided. It is impossible to study any particular kind of organism to the best advantage when another organism is present. Different organisms produce, as a rule, different kinds of growth on the surface of sloped jelly or agar. In some instances the growth is scanty, in others, luxuriant. Some growths are raised, rough or irregular; others are smooth, flat and regular. The common organism known as Bacillus prodigiosus produces a blood-red color; another, the most common pus organism, a golden-yellow pigment; some, like the typhoid bacillus, produce no color at all.

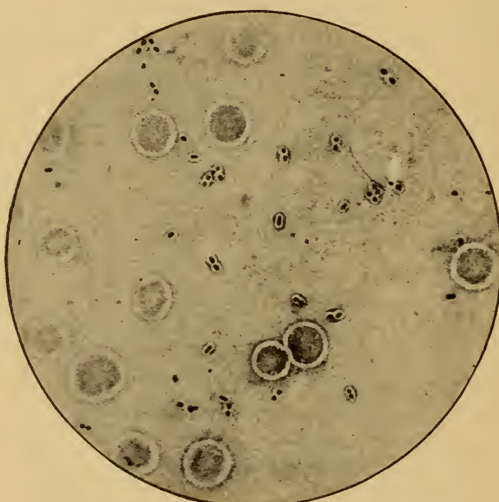


Fig. 49.—Pneumococci.

A microscopic examination of the bacteria present in a colony furnishes additional information. This is accomplished by removing a small portion of the growth and spreading it on a microscopic slide in a drop of water. Some kinds of bacteria will be seen to swim about of their own accord. The property of moving about independently in a liquid, which some bacteria possess, is termed *motility*. They have moving organs known as *flagella*. A large number of bacteria can move about independently. On the other hand, a large group lack this property; they are *non-motile;* they do not have flagella. In addition to motility, the size, shape and other microscopic characters are studied.

While organisms are grouped under the three types previously mentioned, members of each group have distinguishing characteristics of their own, differing in appearance as individuals, and so permitting definite recognition or diagnosis under the eye of the microscope. To make this clear it is but necessary to study the accompanying illustrations which show some of the familiar bacteria.

Fig. 46 is a picture of the anthrax bacillus. Note that these organisms are large and tend to group themselves into chain-like formations. Compare them with the tubercle bacillus (Fig. 42.)

Fig. 47 shows the typhoid bacillus. Notice the differences in the length of the bacilli. Some are quite short, others long; the thickness is, however, uniform. The typhoid bacillus is very small compared with the anthrax organism; also, it differs in the method of grouping, the typhoid bacillus being, as a rule, single, not paired or in chains.

Fig. 48 illustrates one of the pus-producing organisms. This is a coccus and tends to gather in chain-like formations.

Fig. 49 shows another coccus. This is the diplococcus of pneumonia, called diplococcus because it occurs in pairs. Aside from this peculiarity, this organism is surrounded by a peculiar halo-like structure, known as a *capsule*. The large round objects are blood cells.

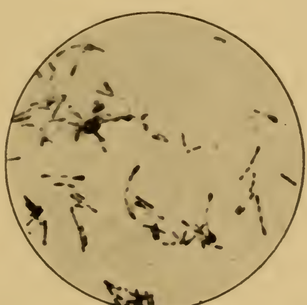


Fig. 50.—One of the very characteristic forms of diphtheria bacilli from blood-serum cultures, showing clubbed ends. × 1100 diameters (Simon.)

Fig. 50 is a picture of the diphtheria bacillus in pure culture. The illustration shows its peculiar, irregular, and more or less granular, club-shaped form.

So it is obvious that these organisms all differ and may be readily distinguished from each other by one who is familiar with them.

BACTERIA IN THEIR RELATION TO DISEASE.

Most organisms encountered in nature are of the harmless kind. Scientificially they are known as the *non-pathogens*, or the *non-pathogenic bacteria*. The non-pathogenic bacteria occur very abundantly in nature. There are endless varieties of them. They are found in the air, in water, in the soil, on the skin, in the mouth, and in the entire digestive tract. Little attention need be paid ordinarily to the non-pathogens insofar as disease production is concerned.

Certain diseases are brought about by specific bacteria which constitute a comparatively small group of microörganisms and are known as the *pathogenic* bacteria, or *pathogens*. By the pathogenic bacteria are meant bacteria which are able to enter the body, to multiply and set up disturbances; in other words, to produce disease. This, then, is the chief distinction to be made between non-pathogens and pathogens, viz., non-pathogens are ordinarily harmless; pathogens are disease producers.

Pathogenic bacteria are organisms which in the usual laboratory tests appear exactly like the non-pathogenic. The only essential difference lies in the peculiar action of the pathogens when introduced into susceptible hosts. Some of the pathogens may be isolated in the manner previously described and then may be studied in their various relationships. The most significant thing about them, however, is the effect that such pathogens have on the host which they invade.

The production of disease by bacteria depends upon two things: (*a*) on the invading organism, and (*b*) on the relative susceptibility or immunity of the host.

(*a*) *The Invading Organism.*—The ability of invading organisms to produce disease also depends upon two things: *First,* their *virulence.* By virulence is meant their ability to produce disturbances when the conditions of the host are such as to permit it. Virulence determines in a large measure whether the typhoid bacillus is going to produce typhoid fever when it enters the digestive system. *Second,* whether any organism in question is going to produce disease or not also depends on its *numbers.* Years ago it was thought that one tubercle bacillus was sufficient to produce tuberculosis, or that one typhoid bacillus was enough to start typhoid fever; but the opinion regarding that point has decidedly changed. An organism that is extremely powerful or very virulent, or an organism that is specially well endowed with the property of producing its own particular kind of disturbance in a very susceptible host, can do its work in comparatively small numbers. In fact, the white mouse and the guinea-pig are so susceptible to tuberculosis that it is claimed one tubercle bacillus may produce tuberculosis when experimentally introduced. On the other hand, calves are not affected seriously by tubercle bacilli unless these are exceedingly virulent and of the bovine type of bacilli.

(*b*) *The Susceptibility of the Host.*—Man is susceptible as a race to typhoid fever. All animals, so far as we know, are immune. On the other hand, the tubercle bacillus is pathogenic in the full sense of the word. There are apparently few species of vertebrate animals which are not susceptible to some form of tuberculosis. Even cold-blooded animals, like turtles and fish, are said to be victims.

How a Pathogen Acts.—When a pathogen succeeds in bringing about bacterial disturbances, it does so in two ways: *First,* it multiplies in the body; *second,* in the light of more recent knowledge it produces *poisons* or *toxins.* It is said that the pathogen differs essentially from the non-pathogen in that the former is able to produce toxins, while the latter is not. However, in order that the pathogen may produce appreciable amounts of poisons or toxins in the human body it must first establish itself. For example, the diphtheria bacillus when it enters the mouth and throat or nose, sets up local disturbances there. It does not enter the blood, except in very rare instances. It multiplies locally usually in the throat and yet the symptoms of diphtheria are not confined to the throat. In diphtheria the important effects are those of general poisoning. There is nervous disorder, fever, emaciation, etc., which cannot be explained on any other ground except that the diphtheria bacillus produces some sort of a poison which is distributed generally throughout the body, and which itself is directly responsible for the disease complex.

The same thing may be said with reference to lockjaw. There is only a local injury, probably brought about by a rusty nail or by an ordinary wooden splinter. If infection takes place, it is confined to the seat of injury, but this local swelling, inflammation and pain are of minor significance. The important factor is the poisoning of the system by the toxins which are produced locally either in the finger, the hand, the foot or elsewhere. It is the action of these poisons that are sent out from this local infection throughout the body, affecting the heart, the nerve centers and other organs, that is so frequently fatal.

Peculiar preventive measures have been evolved against diphtheria and lockjaw. These are to a certain extent even curative in action. The preventive agents are known as *antitoxins*. In diphtheria and in lockjaw infection there are produced what are known as extracellular poisons or toxins. This fact has been demonstrated clearly, for the toxins have been produced under artificial conditions in ordinary beef broth, etc.

Paths of Infection.—When a bacterial disease is produced the organism must have access to the part of the body that is immediately affected. The avenues by which the organism gains its entrance are known as *paths* or *channels of infection*. For instance, in diphtheria the paths of infection are the mouth and nose. Of these the mouth is by far the more important. In lockjaw the path of infection is usually the skin. The lockjaw bacillus enters through a broken or ruptured portion of the protecting tissue of the body. In typhoid fever the mouth, gullet, stomach and intestine constitute the path of infection. Knowing what the particular cause of any disease is and also the paths of infection, make it possible to combat this disease with some considerable degree of success.

The history of cholera may be taken as a good illustration of the value of such knowledge. Ever since 1883 it has been known that cholera is produced by a disease-producing organism termed the cholera spirillum or cholera comma bacillus, so named because at times it looks like an ordinary comma under the microscope, and sometimes like a spiral. It is well known that the seat of infection is the intestine. An organism, then, to produce Asiatic cholera must be the Asiatic cholera organism, and it must have access to the intestine through the mouth, gullet, and stomach. What is the result of the knowledge of these facts alone? The following will clearly demonstrate:

Before the discovery of the cholera organism Europe and America were visited almost periodically by cholera epidemics. These epidemics have, as a rule, had their origin in India. In fact, it may be said that India is the home of Asiatic cholera. It exists there year in and year out. At certain times it breaks out in severe epidemic form, and in some of the great epidemics hundreds of thousands of Hindoos have fallen prey to the disease. In their various religious pilgrimages they naturally carry infection with them from place to place, and thus produce new centers of distribution. It is but natural that cholera should follow routes of travel and in this way become general unless effective preventive measures are employed.

Cholera has spread again and again from India through the rest of Asia and to Europe; it has also periodically invaded America. Some visitations have been very serious. The last cholera epidemic in North America was in 1870 and 1871. Practically nothing was known about cholera then, aside from its telling effect. In the last epidemic, the national authorities made a very strenuous effort to cope satisfactorily with the situation. They strengthened their vigilance at the ports where European ships entered; they improved their system of cholera prevention in general; but even then health officers were practically helpless until they acquired the information that cholera is caused by only one particular kind of organism, that this organism establishes itself in the intestine and there does its injurious work.

A few years ago Russia was visited by one of these epidemics. The disease spread through Moscow, through St. Petersburg, and in fact lingered on the borders of Russia for two years or more. Hundreds of cholera victims died daily in some of the large cities. Germany was constantly on the lookout for the imported cholera cases. The border was carefully patrolled on the Russian side. Not only that, but every person entering Germany who excited the least suspicion as to being a cholera carrier was followed to his destination and put under severe scrutiny by the officials. In spite of this vigilance there were at least one hundred isolated cases of cholera in Germany. These cases were distributed throughout Germany. They were cases that were introduced mainly from Russia, but they remained individual isolated cases and did not spread the disease.

All sorts of laboratory tests have been made in Germany and in our own laboratories in New York, in order to prevent persons from actually entering and taking up their abode in this country who were not only infected with cholera but were what we call cholera carriers. They even went so far in New York as to make individual examinations of all steerage pasengers on steamships coming from cholera-infected foreign ports. That was the end of the introduction of even sporadic cases of cholera into the United States.

Here, then, is a good illustration of what the discovery of the particular pathogen and the determination of the path of infection through which that pathogen must travel in order to set up its disturbance and produce the disease in question will do from the standpoint of prevention. And this same principle applies generally. For example, the plague, which has been so common in India, China, Japan and the Philippines, is another illustration. In the past there have been large epidemics of plague in those countries. Even San Francisco was plague-ridden several years ago.

In the last ten or fifteen years we have come to feel as secure in this country against plague as against Asiatic cholera. Such a feeling of security did not exist twenty-five years ago, because at that time little or nothing was known about the plague bacillus, and of the methods by which it could pass from one individual to another and produce plague.

When it was determined that plague may be transmitted from man to man through the agency of the rat and the rat flea, a great forward step was made. Rats are a severe menace in any community which is threatened with an invasion of bubonic plague. One may ask how rats in themselves can be a menace. Rats are naturally infected with fleas, and it has been shown by actual experiment in India and elsewhere that these fleas pass not only from one rat to another, but they may pass from rat to man. It has also been shown experimentally that a rat flea which has left a rat infected with bubonic plague, when it bites another animal, is likely to introduce the germ of bubonic plague with the act of biting. This knowledge has done a great deal to solve the problem of plague prevention.

Comparatively recently another big chapter was added to the history of plague prevention. There was a recent epidemic of plague in Manchuria. Previous to this it was believed that rats and rat fleas alone played the important part in the transmission of this disease. However, it was demonstrated clearly that in Manchuria the rat did not play much of a part, but that the plague there was of a peculiar pulmonary type, very much like ordinary consumption; that the plague bacillus was spread, not through the rat, but from person to person by ordinary coughing or talking. Acting in accordance with this important information the medical authorities soon rid Manchuria of its epidemic. Physicians and nurses who attended the patients remained, with very few exceptions, absolutely free from the disease, by guarding themselves against infection with the aid of face masks, long coats, etc.

The Mouth as a Path of Infection.—Many, and perhaps most, of the organisms that are now known to be the real causes of disease are eliminated through the mouth or intestine, and enter the future victim through the mouth as the important channel. Following are some significant examples.

In diphtheria the organism has as the path of infection the mouth, nose, and the throat. In tuberculosis the channel of infection is the mouth, windpipe, and the lungs, or the mouth and digestive tract. In follicular and other presumably infectious types of tonsillitis it is apparently the mouth. In the epidemics of milk-borne sore throats that have occurred in Boston, Baltimore, Chicago, and other cities, in the last few years, the channel of infection was the mouth. In dysentery, and in pulmonary plague, are found additional illustrations. Many authorities claim that the organism of smallpox probably enters through the mouth or nose. The same idea is held by some with regard to measles and mumps. Whooping-cough and influenza fall in this category. There are very few of the well-known infectious diseases that are not brought about by the entrance of the organism through the mouth, or the mouth and nose.

This of course is of special significance in the work of the dental hygienist, for a clean mouth necessarily means a lessened danger of infection through that channel.

Tuberculosis may be produced by breathing the tubercle bacillus, or it may be produced, as many claim, as the result of swallowing the tubercle bacillus, as in milk.

The fact that tuberculosis of children is often associated with the intestine has brought forth the theory that milk-borne tuberculosis is a not uncommon thing; that tuberculosis, particularly in the child, may be brought about by the use of milk from tuberculous cows. If this is true, man is susceptible not only to the human type of tuberculosis, but to bovine as well, and may contract tuberculosis through at least two different channels of infection, namely, the mouth and the trachea on the one hand, and the mouth and the digestive tract on the other.

All of these efforts to study the various diseases from the standpoint of prevention have resulted in at least partial success.

BACTERIOLOGY AND HYGIENE.

It is rather difficult to divorce the subject of bacteria from hygiene, and the relation of bacteriology to public hygiene is of great interest. In this connection a few figures regarding the diphtheria death-rate in Prussia in 1876 as compared with 1909 are convincing. In 1876 the death-rate was 16.3 per 10,000 as compared with 2.5 in 1909. The tuberculosis figures are as follows: In 1876 the death-rate for Prussia was 30 per 10,000, while in 1909 it was only 16, a reduction of about one-half. In Massachusetts the figures compare quite favorably with those just mentioned. Such figures are most gratifying. It was in 1883 that Koch made his famous discovery of the tubercle bacillus, and from that time on the main emphasis in prevention was directed in such a way as to combat the tubercle bacillus and prevent its spread from person to person, which accounts in a large measure for the remarkable progress that has been made.

One prominent English authority said a few years ago that if the decrease in tuberculosis continued for fifty years as it had done for the past ten or fifteen, that tuberculosis would be completely wiped out. The numerous health resorts, tuberculosis sanitoriums, various methods of dieting, exercise, medical examination, etc., all have had their telling effect.

It is claimed that in our own country the death-rate from diphtheria has been reduced fully 75 to 80 per cent. There are various things that contribute to this enormous reduction of the death-rate from diphtheria. First of all, there was the discovery of the diphtheria bacillus, and the efficient system of laboratory diagnosis of the disease. Diphtheria and tuberculosis are now diagnosed by laboratory methods in all cities of any size in Europe and in this country. Second, the use of diphtheria antitoxin. This has played an immense role in the lowering of the death-rate from diphtheria. Finally, our system of quarantine, which has grown out of the knowledge that diphtheria is infectious and is spread from mouth to mouth, is of much importance.

In the field of malaria prevention, it is known that in some communities, particularly in the Panama Zone, malaria has been practically eradicated. The general death-rate among our laborers in Panama is below that of New York. When the Panama railway was built the main obstacle in the construction of that railway, and also at various times in the past history of the canal enterprise, was the prevalence of deadly tropical diseases, namely, malaria and yellow fever. Yellow fever is practically unheard of today in the isthmus; malaria is under control.

In Cuba yellow fever has been stamped out. For a number of years there was not a single case in Havana. That was soon after our army commission made its wonderful study of the problem of yellow fever in Cuba. It was soon after their demonstration that yellow fever was transmitted from mosquito to man; or, in other words, that yellow fever required as an intermediate host the mosquito known as the stegomyia, or yellow fever mosquito. That work has been substantiated, and the methods of prevention of yellow fever that were put into effect have resulted in its being stamped out in Cuba, in the Canal Zone, and in the Gulf States where a few years ago it appeared and assumed threatening proportions.

FERMENTS.

In the chapter on Physiology organized and unorganized ferments are mentioned. As stated there, many different unorganized ferments are present in the human body. They are known, in other words, as *enzymes*.

The *unorganized ferments,* or enzymes, *are not living things.* They are the products of living things. On the other hand, the *organized ferments are living things,* although they may be single-celled.

One of the best *examples* of organized ferments is ordinary bread yeast, or beer yeast; they are very much alike. Of course, the word "ferment" is suggested by the very activities of the ordinary bread and beer yeasts. These are characterized in their real activities by the fact that they produce *alcohol* and *gas.* Beer yeast produces considerable alcohol. The gas is known as carbonic acid, or carbon dioxid gas.

It has been known for some time that the food substances upon which these yeasts act are chiefly sugars and sugar-like substances. Most of the yeasts require sugars, such as malt sugar, or grape sugar. But it should not be taken for granted that sugars are foods for yeasts only; they are food for many kinds of bacteria, as for example, some of those which are found in the mouth and in milk.

In beer fermentation, where the beer yeasts are involved, the alcohol is the ordinary alcohol known as beer or wine alcohol. These yeasts have their peculiar process of multiplication, namely, that of budding. They are primarily fermenting organisms, and are so called because they produce gas and alcohols from sugars. There are a large number of bacteria that will ferment just as the yeasts do. Some of them may be bacteria of comparatively large size. Some are more or less closely related to and have certain things in common with yeasts. Then, again, the common bacteria, like some of the smallest bacteria of the mouth, the ordinary bacteria in milk, or the milk-souring bacteria, are fermenting organisms. They are organized ferments. They are agents or microörganisms that act upon sugar as well as other food substances, like proteins. *Bacteria,* like yeasts, are *organized ferments,* in distinction from ordinary enzymes, or unorganized ferments.

FERMENTATION AND PUTREFACTION.

Fermentation and putrefaction are produced by bacteria. This means that bacteria are able to act upon various kinds of food substances, splitting them up into many components. Some bacteria will split these food substances into so many and such varied parts that the complete array of them is quite surprising. This is particularly true of the so-called putrefying bacteria, or putrefiers, *i. e*, those that are responsible for putrefaction.

Frequently a *distinction* is made between *fermentation* and *putrefaction.* In some dictionaries fermentation is referred to as any decomposition of organic matter by microörganisms, and the products may include all products of bacterial decomposition. In the more strict or more limited sense, however, *fermentation* applies to the peculiar action of yeasts or bacteria which *involves* the destruction of *sugar,* or *sugar-like substances, i. e.,* the carbohydrates. Real *putrefaction* means *decomposition* of *albuminous substances, i. e.*, proteins. In a purely scientific sense putrefaction is that kind of albumin decomposition which is so well illustrated by cadaveric putrefaction, the putrefaction that is accompanied by the evolution of products that have a very offensive odor, as the natural decay of any dead animal body. Such putrefaction can take place in the absence of oxygen. This kind of putrefaction occurs in deep cavities in teeth in which lodged food has for some time been undergoing decay and free atmospheric oxygen has been excluded.

Certain kinds of bacteria are both fermentative and putrefactive, acting on both sugars and proteins. Some are fermentative only, in the pure sense of the word; others will attack proteins only. Certain organisms are able to decompose various kinds of sugars; others will attack only the simpler ones, like grape sugar, and have no power at all to decompose other carbohydrates.

Examples of fermentative organisms may be found among the common bacteria of the mouth, and the ordinary acid-producing bacteria in milk. Among the fermentation products are acids of various kinds, especially lactic and butyric acids. Other decomposition products are carbon dioxid (CO_2) and, in some instances, alcohol. The different acids can be identified. Any organism which is able to produce both fermentation and putrefaction prefers, as a rule, the sugar, and there is pronounced acid production long before any sign of bacterial putrefaction. Hence, protein decomposition is for the time prevented, and will take place only after the sugars are used up. The acids may increase in sufficient amount to hold back the growth of the bactera that produce them, just as in the case of yeast fermentation the alcohol after a while prevents further development of the yeast cells that produce it. Alcohol and carbon dioxid are the characteristic products of yeast fermentation, though they may be included among the decomposition products of other bacteria.

In order to study putrefaction and putrefactive products we must choose an organism that has the ability to decompose a protein like those of ordinary blood serum or egg white. When these albumins are heated sufficiently they begin to thicken or coagulate. They do not stand heating without a change in their physical character. When these coagulated proteins are subjected to putrefactive decomposition the first visible change is usually the solution or liquefaction of the insoluble matter. Soluble proteins are first produced. These are broken up into smaller and smaller products until the final stage of putrefaction is reached.

PUTREFACTION AND DIGESTION.

An analogy may be drawn between general putrefaction and ordinary digestion in the human body. The soluble proteins (immediate products of decomposition) will stand heating. They may be heated in aqueous solution, and they will not harden or coagulate. Peptone, for instance, is one of these. Peptone and albumose are the immediate products of enzyme action upon protein. Exactly similar conditions are found in bacterial decomposition of proteins. Not only are there these early products of ordinary pancreatic digestion, but also various other products that are common to both processes. Up to a certain point bacterial decomposition follows the very same phases or stages as those seen in pancreatic digestion. The next products after soluble proteins are, among others, tyrosin and leucin, which are important nitrogenous substances. They are not albuminous in character any more. They are comparatively simple products.

There is another important product that is common to bacterial and tryptic digestion, namely, tryptophan. In real putrefaction there are subsequent phases, however, which distinguish bacterial decomposition from ordinary enzyme action.

When putrefactive processes are allowed to continue indefinitely, or until the final stages are reached, the characteristic putrefaction products known as indol, skatol, phenol, and frequently mercaptan are formed; also hydrogen sulphide, and finally the simple products, ammonia, hydrogen and carbon dioxid.

BACTERIAL POISONS.

A great deal has been said in past years about bacterial poisons known as *ptomaines*. Brieger succeeded, apparently, in isolating many of the so-called ptomaines. He did more along this line of investigation than anybody else. He had his own peculiar methods of isolating from various bacterial mixtures chemical substances that were very toxic to animals; but many of these toxins were in all probability the result of the vigorous treatment to which the bacterial mixtures were subjected in the process of purification, instead of being original bacterial products.

The former idea of ptomaines has been greatly modified in recent years, because much that had been said about ptomaines could not be substantiated. It was said that cheese at certain stages contained ptomaines or bacterial poisons; that milk if it were kept in the ice-box too long might be extremely dangerous because it contained bacterial products known as ptomaines; that canned foods were frequently dangerous, for the same reason. This may be true, but the action of ptomaines as poisons has in the past been greatly overestimated. It is now thought that bacteria may produce products in the process of decay which are more or less injurious, but they are harmful in the sense that any foreign substance is harmful when it gets into the system. If foreign animal or vegetable matter is introduced into the circulation of an animal, serious reactions may occur, even though the tissues so introduced are normal tissues, like blood, etc. Foreign substances in themselves are harmful, when introduced into the blood circulation of animals. In this sense many bacterial products and bacteria themselves are injurious, but this does not signify that they are necessarily toxins or producers of toxins.

There is much misconception as to the significance of toxins. Real toxins are known in connection with specific kinds of bacteria which have, in addition to their property of producing various decomposition products, the peculiar ability to produce special substances known as poisons or toxins.

It is assumed, for example, that the ordinary pneumococcus, an organism present in the mouths and lungs of pneumonia patients, produces a specific pneumonic toxin. But in ordinary dental decay there is no indication that the bacteria involved are toxin producers, although it is quite probable that the continued absorption of their products by the body is harmful.

The various disease-producing organisms are characterized by the fact that they produce their own peculiar toxin or poison. In lockjaw, for instance, a poison is produced which is very closely related to certain powerful vegetable poisons known as ricin and abrin. Chemically they are not the same, but in their intensity of action they have much in common.

IMMUNITY, VACCINES AND ANTITOXINS.

It has been previously stated that general infection depends upon two things: (1) the virulence of the infecting agent, and (2) the relative susceptibility or immunity of the subject.

There are two *kinds of immunity:* (*a*) *natural* and (*b*) *acquired*. *Natural immunity* may be inherent owing to some peculiar process in racial development that cannot be explained. For instance, man is immune to fowl cholera, while the barnyard fowl is very susceptible to it. The human race is susceptible to the typhoid bacillus. The fowl, on the other hand, does not contract typhoid fever; in fact, none of the lower animals do. All species are apparently susceptible to tuberculosis.

Susceptibility may vary in a family. One member may be extremely prone to tuberculosis or typhoid fever; another may be comparatively immune. It is impossible to say why. Susceptibility also varies from day to day, and, in fact, from hour to hour. The immunity of the individual is never constant.

Immunity varies among individuals of the same species, and in the same individuals. There are persons who carry the typhoid bacillus in their intestines day after day and have never shown signs of typhoid fever; diphtheria-carriers are often immune to diphtheria.

Acquired immunity is that which results from specific infection or poisoning of one kind or another, or is the result of treatment with immunity-conferring agents like antitoxic sera. Actively acquired immunity differs from passive immunity in that it is the result of an actual disease process.

A person who has gone through smallpox has attained actively acquired immunity. Another individual may be more or less immune to smallpox, by virtue of a relatively high degree of natural immunity.

Acquired immunity may be naturally or artificially produced. In the laboratory it is possible to bring about artificial immunity by inoculating a guinea-pig with a microörganism that is pathogenic for this animal. For example, a broth culture of the diphtheria bacillus, or its poisons, may be injected in small amount under the skin of a guinea-pig. If the dose is very toxic, or if the organism is virulent enough, the guinea-pig will die in a very short time. If the dose is not fatal, the guinea-pig may show signs of disturbances, but it will soon recover. A second and larger dose is then injected under the skin and the guinea-pig in due time recovers from the effect of this also. If the injection be repeated several times, such a high degree of immunity will be reached that relatively large amounts of the bacillus or toxin may be given without any evil effect. Artificially acquired immunity has thus been brought about. The process is analogous to that which takes place in a diphtheria-infected child. The symptoms are different, but the process is essentially the same. The child has naturally acquired the disease, while the guinea-pig artificially acquired it.

Vaccines.—Not only living, but dead bacteria may be employed to produce immunity. Such a preparation is known as a *vaccine,* which is, as a rule, nothing more than a *mass of dead bacteria and their products,* suspended in a suitable medium. Such a vaccine when properly applied will produce partial or complete immunity. The method of application is often by hypodermic injection.

In immunization against typhoid, plague, chronic abscesses, especially internal abscesses, etc., cultures of the specific bacteria in question are used. The most common organism in abscess pus is known as the staphylococcus. The staphylococcus vaccine is usually prepared from the particular organism that is causing the abscess in question, if it is possible to isolate it. Such a vaccine is called *autogenous, i. e.,* it is a vaccine prepared from the very organism that is causing the trouble. This bacterium is isolated by obtaining a specimen from the seat of injury and cultivating it in an artificial medium. Before the vaccine is used the bacteria are killed by heat. In the preparation of a staphylococcus or streptococcus vaccine heating at 58° to 60° C. for about one hour is sufficient to kill all of the micrococci. The vaccine is therefore a suspension of dead bacteria. Some vaccines are now being advocated in which the microörganisms have not been killed, but the use of such vaccines is accompanied by more or less danger from infection. Vaccines which have been heated and still retain their power to produce at least partial immunity, are of much value, and comparatively safe.

Pathogenic staphylococci and streptococci admirably serve for the preparation of the autogenous vaccine. A suspension of these organisms which have been isolated from the patient in question, or from the abscess itself, and grown in pure culture, is heated at 58° to 60° C., for one to one and a half hours, and then standardized. This constitutes the final vaccine. In *standardizing* vaccines, the bacteria are counted under the microscope, so that the strength of the suspension may be known, and the necessary dilutions made.

What do vaccines do when intelligently used? They are not able to effect serious injury, but may produce the disease in question, in very light form. The symptoms are so mild, as a rule, that they are borne with little or no discomfort. A person receiving an autogenous vaccine, or any other kind of vaccine, is subjected to a method of active immunization.

Vaccine is now being used for the prevention of typhoid fever. Many persons going to the tropics resort to antityphoid inoculation. The vaccine is injected with a small hypodermic needle under the skin of the arm. Two or three injections are made at intervals of a few days. One half to one billion of bacteria are introduced during each treatment. After the first injection there is often a little rash and some irritation. Sometimes there is a rise in temperature and slight bodily ailment. These effects pass off very soon, however, and the subject becomes normal. Real typhoid fever cannot be produced without the living typhoid bacillus, so there is no danger of producing the disease by injecting this vaccine. Persons who receive two or three vaccine inoculations against typhoid are likely to be relatively immune to an attack of typhoid in the course of the next year or two at least. *Vaccination*, therefore, is a process of partial, active immunization.

Antitoxins.—In the *manufacture of serum*, or, in other words, *antitoxin production*, several steps are necessary, which are altogether different from those followed in vaccine production. A child who receives diphtheria antitoxin is made artificially immune by this substance; but he is not put through an active course of diphtheria to acquire this immunity. There may be a little rash and a few other minor disturbances when the antitoxin is injected, but none of the real symptoms of diphtheria occur. When antitoxin is used to prevent or cure, the child receives into his system an agent which confers passive immunity. This active agent is present in the blood serum of a horse that has been actively immunized against diphtheria. Immunity is then passively conferred upon the child by the horse, the blood of the horse containing the diphtheria antitoxin. The horse does not acquire what is called diphtheria, but has, nevertheless, been put through a process of immunization, by actual poisoning, not with the diphtheria bacillus itself, but with its poison or toxin.

Technic of Making Antitoxin.—A small dose of diphtheria toxin is injected under the skin of the horse. After the reaction is over the horse receives a larger dose of the toxin. This dose is increased and repeated until the horse ceases to be visibly disturbed. At this stage the blood is known, by specific tests, to contain an abundance of the antitoxin. The blood is tested by drawing it from a vein and determining its power to prevent death in an animal which is inoculated with a fatal dose of diphtheria toxin. A single horse may furnish sufficient antitoxin to protect hundreds of persons against diphtheria.

Vaccines are more beneficial as preventive than as curative agents. Only in comparatively few cases does marked improvement occur when vaccines or antitoxins are used after disease has once set in. Typhoid vaccine is of much value in preventing typhoid fever, but not of much importance as a cure.

IMMUNITY.

Theories of Immunity.—The theories of immunity have always been a subject of great interest and may be discussed with profit.

A person may become actively immune by going through an attack of smallpox. The individual, after recovery, is immune at least for many years. One may be vaccinated against smallpox and go through a mild attack of disease somewhat akin to it, and acquire immunity which lasts for at least several years. Now, why is immunity acquired after having gone through the natural disease, and why is an individual immune to smallpox for several years at least, after having been vaccinated successfully against smallpox?

Why does the child who recovers from a severe attack of diphtheria remain immune to diphtheria for some time to come?

The answers to these questions are difficult ones, and are merely theories and hypotheses. However, in these cases theories are of value because they are working hypotheses. In the laboratory an endless amount of experimental work can be done with the aid of some of these important theories of immunity. Furthermore, they are important factors in modern preventive and curative medicine.

One of the old theories that has merely an historical interest is *the theory of retention,* which was advanced many years ago. According to this theory certain chemical substances are retained in the body during the progress of the disease, just as in culture tubes all sorts of bacterial products accumulate. These retained substances become so abundant that the bacteria that have produced them are unable to grow any longer, and they succumb to their own poisons.

Another old theory is *the theory of exhaustion.* This is equally unworthy of serious consideration, but at the same time it is interesting historically.

According to the theory of exhaustion the bacteria, after they have multiplied in the body of the host for a certain length of time, have used up the most desirable and nutritious material or pabulum, and are unable to thrive any longer.

Both of the above theories have been set aside.

Metchnikoff originated a most ingenious theory, which, up to ten or fifteen years ago, was looked upon with a great deal of favor.

This is to the effect that the animal body is normally endowed with certain elements which have, as one of their chief functions, the destruction of foreign substances which invade the body. These elements are certain white blood cells which are called phagocytes; hence the term phagocytosis. This is the theory of phagocytosis:

In the blood there are various chemical substances in solution, as for example, albumin. There are also insoluble elements or suspended cells that are called blood corpuscles. Of these the most conspicuous are the red and white cells. The red cells contain the coloring matter, and play an important part in the oxygenation of the tissues of the body.

These red cells according to the Metchnikoff theory have nothing to do with immunity, but the white cells, or leukocytes play an important part.

A concrete example of phagocytosis may be given. A person who has gone through an attack of pneumonia, has become immune. According to Metchnikoff, when new pneumococci invade this person they are destroyed very soon by the white blood cells known as phagocytes. The phagocytes which come into contact with these organisms take them within themselves and destroy them by a process of dissolution and digestion. In a susceptible individual the phagocytes are so few, or they are so weak that the invading bacteria gain the upper hand and disease develops.

These phagocytes may be seen at work under the microscope. If a large bullfrog is given a mild attack of anthrax by injecting a pure culture of this bacillus into one of the lymph spaces on the back or abdomen and then the lymph of the frog is examined, a most interesting picture will be observed. The anthrax bacilli will be seen lying within the phagocytes, some apparently unchanged and normal, with definite outlines, as if they were still able to multiply and perform their various functions, while others are in the process of disintegration.

Metchnikoff's theory for a long time received much support, but finally had to be materially modified.

Certain of the blood leukocytes, the phagocytes, according to Metchnikoff's idea, are able to ingest and destroy invading foreign organisms, and, among them bacteria, but they are unable to do this unaided; they require assistance of certain chemical immune substances known as *opsonins* which are present in immune blood in varying amounts. The theory of phagocytosis is still maintained, but in modified form.

The most interesting of all theories, and probably the most important in many respects is *Ehrlich's side-chain theory*.

As an example it will be assumed that a child is recovering from diphtheria. By experiment it is known that while the child is throwing off the disease or is recuperating, it is fortifying itself against future attacks, and also against further injury from the present attack.

It has been demonstrated again and again that if a small amount of blood be taken from a person recovering from diphtheria, or from an immunized animal, and be brought in contact with an ordinarily fatal dose of diphtheria toxin, that the diphtheria toxin is neutralized, and is harmless when injected into a susceptible animal.

In other words, the serum of the blood of an animal which has been immunized against diphtheria has the property of protecting a normal guinea-pig against a fatal dose of the toxin. If this is so, then it must be assumed that when a person throws off the disease, or recovers completely, he has produced something in his own body which is injurious or antagonistic to the bacteria and toxins that in the first place produced the disease. Hence the terms antitoxins and antibodies. An antibody, therefore, is nothing more than something which has been produced as the result of poisoning or infection, a substance or substances within the body, which counteract and neutralize the poisons or the bacteria in question.

Ehrlich's Side-chain Theory of Immunity.—*Toxins* are peculiar chemical substances that may be characterized as possessing two distinct functional parts, one that acts as the poison, and the other that serves as a link to connect the toxin with tissues that are attacked. The former will be called the poisoning group, and the latter, the combining group. As long as toxins are uncombined with the tissues they are harmless, but just as soon as the combining group comes in contact with any part of the tissue the poisonous group exerts its poisonous action. Without this combination the toxin is absolutely harmless.

In the natural course of events the toxins actually do find occasion to combine with some of the tissues. The parts of the attacked tissues to which the toxins become attached are called by Ehrlich *receptors* or *side chains.* More and more toxins combine with side chains as this process goes on, until there comes a time when the subject responds in one of two ways, *i. e.*, he either succumbs to the disease or begins to make his recovery. If he recovers, the following explanation is given in the Ehrlich theory: When the toxins combine with the side chains, the tissues which are affected *cast off* the poisoned side chains and immediately produce new ones to take their place. The injured side chains are thrown off in order to protect the main tissues or cells themselves. They have simply been sacrificed and float about in combination with the toxins whose action they neutralize. Finally, they become dissolved or digested by the body fluids. But a most interesting fact is that these tissues have the peculiar property of some of the lower animals, like the salamander, of restoring lost members. These tissues, when they lose a side chain, immediately replace it. If they lose two side chains, they replace them. If they lose a thousand, they will replace a thousand, and soon they acquire the habit of reproducing not only the lost receptors, but more than the number sacrificed, and so where one side chain has been lost there will be dozens to take its place. The cells have produced these side chains in such large numbers that the toxin is insufficient in amount to combine with all of the newly formed receptors. Furthermore, the side chains are produced in such large numbers that the tissue cells cannot hold on to them any longer. The body fluids become filled with these free receptors which are now known as the *immune bodies* or *antitoxins.*

The *antitoxins are the side chains* that have been produced in such large numbers that the very tissues from which they were generated can no longer retain them, and they are shot off into the circulation and remain there as safeguards against any other toxins that may invade the tissue. If toxins present themselves, they will combine with these free antitoxins and thus no injury will be wrought on the tissues. The antitoxins are in the blood floating about freely, and combine with the individual toxins, neutralizing them, and preventing the toxins from getting at the living sensitive tissues themselves.

This is one of the most ingenious and at the same time one of the most satisfactory theories of immunity.

STERILIZATION AND DISINFECTION.

There are three important phases of this subject that have received a great deal of attention: (1) asepsis; (2) antisepsis; and (3) disinfection. The actual distinctions are important.

In *asepsis* there is what the term implies, absence of infection, or absence of sepsis; that is, in asepsis living bacteria are excluded, and where microörganisms do not exist there can be no such thing as antisepsis or disinfection. The idea of asepsis is coming to the front more and more in surgery, and, to a large degree, actually supplanting disinfectants and antiseptics.

The second phase, that of *antisepsis*, has its own significance. Various food substances are preserved by means of chemicals. The salting or curing of pork is an instance. If a thorough bacteriological examination of cured pork were made, it would not be found sterile but would, in all probability, be found to contain any number of bacteria. But there is an antiseptic condition, and the bacteria that are present are *unable to multiply appreciably* under such conditions. *An antiseptic is an agent which prevents growth and multiplication of bacteria but does not destroy them.*

The third phase, *disinfection*, deals with agents that *destroy* or *remove bacteria*, and therefore is entirely different from either one of the other two phases. Asepsis means no bacteria. Antisepsis means the holding in check of bacteria that are present. *Disinfection means the destruction or complete removal of all bacteria.*

On entering a modern surgical operating room one is impressed with its appearance. The most up-to-date surgical ward now depends more on asepsis in ordinary surgical operations than on the other two phases of the subject. The instruments *must* be sterilized. The hands of the surgeon and his assistants are thoroughly cleaned and disinfected. In some of the best hospitals they do not even depend on washing and sterilization of the hands, but use gloves that have been sterilized and kept in an antiseptic solution. The air should be perfectly still. There are operating rooms where persons are prevented from coming into the room or anywhere near the patient operated upon, until they put on long, sterilized coats. Furthermore, those who perform surgical operations frequently have a mask over their mouth, so as to prevent infection of the patient by mouth spray. No mouth is ever found to be sterile, and it is doubtful if it ever will be possible to sterilize the mouth, so there is no such thing as asepsis in dentistry in the pure sense of the word. But asepsis is an important factor insofar as the hands and the instruments are concerned.

It may be said that disinfection involves the absolute destruction of all forms of life. The term is often misused, as for example, in connection with the pasteurization of milk. Sterilization of milk means the destruction of all microbic life, including spores. Sterilization of milk, or sterilization of water, is real sterilization only when all organic life is destroyed.

There are different degrees of purification by heat or chemicals. *Pasteurization* of milk is an important example of *incomplete sterilization*. It is neither antisepsis nor disinfection nor sterilization. It is the destruction of the comparatively non-resistant types of bacteria in the milk. Spores and a small number of resistant vegetative forms are not killed. In pasteurization the heat used is far below the real temperature for sterilization. In the ordinary pasteurizer the milk is heated at a temperature of 140° to 145° F., for a period of twenty to thirty minutes. Milk that is pasteurized at such a temperature will keep much longer, and is less apt to cause disease than the unpasteurized. If disease-producing bacteria, like the typhoid and the tubercle bacillus, were present, they have been destroyed in the process, and the milk has been made safe. But that does not mean that this milk, when it is put in the ice-box or allowed to stand on the kitchen table, is not undergoing any further chemical or bacterial change. Pasteurization simply holds in check. It corresponds to antisepsis, but is not antisepsis, because the pasteurization is temporary. In antisepsis the antiseptic influence is permanent.

Methods of Sterilization.—In *disinfection* or *sterilization* various agencies may be employed to bring about the desired result. One of the most efficacious, and one of the most practical and reliable means of sterilizing objects is *heat*. Heat is perhaps the most important of all sterilizing agents, and, of course, in many professions it is indispensable as such.

Sterilization by dry heat is a method that is commonly used in laboratories and hospitals. Glass plates or Petri dishes are sterilized, before they are used, by the hot-air method of sterilization. Test-tubes are often sterilized, before filling, in the same way.

There are many occasions on which the dry-heat method cannot be used and another method of sterilization must be resorted to, namely, *moist heat.* Dry heat may be applied only to certain objects that will stand it. It is not safe to sterilize ordinary fabrics with dry heat, as they are apt to become discolored and charred.

Steam heat will often take the place of dry heat, and is an important means of sterilization. The sterilization of towels, of dressings, of media that are used in the ordinary laboratory work, and a large number of other objects that cannot be subjected to dry heat are advantageously sterilized in this way.

A word may be said about the comparative efficacy of dry and moist heat. While *dry heat* may char or discolor cotton and woolen fabrics, it *is not nearly as effective* in its destructive action on bacteria *as moist heat* at the same temperature. This fact should always be borne in mind. An illustration may be given. Some bacteria, like the diphtheria bacillus, will stand a temperature as high as that of boiling water for a short time when in a dry condition, whereas a moist temperature of 150° F. applied for the same length of time is fatal. In other words, moist heat is effective at relatively low temperatures, whereas dry heat is often ineffective at even relatively high temperatures.

Spores are unusually resistant to heat and other sterilizing agents. They will often withstand a moist temperature of 212° F. for an hour. When dry heat is applied it is necessary to raise the temperature to at least 300° F. and maintain it for an hour.

Frequently it it not necessary to destroy all spores, but only such organisms as possess disease-producing powers. In such instances, boiling for fifteen to twenty minutes, with a small amount of potash or soda may be sufficient.

Since in the use of surgical and dental instruments there is always some danger of lockjaw infection (caused by the lockjaw bacillus or its spore), thorough disinfection should always be made.

Some things are sterilized under pressure. The ordinary barber-shop sterilizer, a big globe-shaped apparatus, is a valuable instrument for sterilizing towels, brushes, etc. The objects to be sterilized are put in, the door is placed in position, and steam is generated by means of a gas lamp, or is introduced through a steam pipe. The increase in the pressure of the steam becomes such that the temperature can be raised considerably above that of boiling water. Thus, within certain limits, any temperature may be obtained.

Ordinary boiling is not sufficient for absolute sterilization. Wherever complete sterilization by moist heat is required, it is imperative to use a sterilizer that will heat under extra pressure, or to use some chemical agent which lowers the sterilization temperature. When instruments are boiled in water it is advisable to add a small amount of a solution of soda or potash, for the purpose of lowering the sterilization temperature, and of preventing the instruments from rusting.

Chemicals.—There is another method of disinfection, that is by means of *chemicals.* A great deal is being done today in the disinfection of water supplies, of all sorts of surgical instruments, clothing, etc. Also in aerial disinfection of rooms, as with formaldehyde. The disinfection of the interior of rooms, including the hangings, and all sorts of articles that may have become infected by some occupant who has had some infectious disease, has been practised for many years. In the purification of water supplies one of the best disinfecting agents employed is chloride of lime.

A disinfectant that is being extensively used in surface disinfection of the body is iodine in the form of tincture of iodine. This may be applied externally only. The choice of a disinfectant depends upon the specific object to be disinfected, and in many cases, upon the bacteria and spores that it is intended to destroy.

Corrosive sublimate and carbolic acid have been used for years as general disinfectants for the hands and for different portions of the body and body wastes. The bichloride, usually in 1 to 1000 dilution, and the carbolic acid in the proportion of 1 to 35 to 1 to 50. In fact, mercury bichloride, or what is known as corrosive sublimate, has been used in past years to a very large extent in connection with surgical operations. Today there is a growing sentiment against corrosive sublimate, especially as an internal disinfectant. It contains mercury, and for that reason it is useless in the disinfection of metallic objects because it attacks the metal, forming an alloy with it.

Then there are other facts that make corrosive sublimate and carbolic acid as well more or less worthless. Both, and particularly the former, will combine with various chemical substances, like protein, and lose their disinfectant properties.

Another disinfectant that has been used a great deal is formalin, or formaldehyde. In house disinfection it is used as a spray, or as formalin vapor. Permanganate of potash and formalin are now used in combination for the evolution of the disinfectant vapor, the permanganate serving simply to generate heat by its action on the formalin. A certain amount of moisture is always necessary, to obtain a high disinfectant efficiency.

Sulphur also has been used a great deal for aerial disinfection of the interior of houses, but it is useless unless there is an abundance of moisture, which combines with the sulphurous gas, to produce sulphurous acid. While this product is a powerful disinfectant, it is also destructive to furniture, hangings, wallpaper, etc.

It is impossible as yet to name a completely satisfactory chemical disinfectant, although in recent years many new ones have been put on the market. How often does the dentist take his instruments, dip them into carbolic acid, take them right out again, and assume that they are sterile and ready for further use. *That is not disinfection.* If a chemical is to be used as a disinfectant, it must either be extremely powerful, or the time that is allowed for the disinfectant to act on the subject to be disinfected must be considerable. It is for that reason too, largely, that boiling with a little alkali is taking the place of chemical disinfection of one sort or another, as for example with carbolic acid, carbolized vaseline, etc.

In determining the *value of a disinfectant* several points are taken into consideration. The time during which the agent is allowed to act is an important factor as well as the temperature. In many cases the efficiency increases with increase in temperature. Then the conditions under which disinfection takes place are of much significance. A good disinfectant will not lose its power by contact with proteins, carbonates and other chemicals. Finally, it must be efficient as a disinfectant, but harmless to man or animal.

Alcohol in a dilution of 40 to 80 per cent. serves as a valuable disinfectant, under certain conditions. Recently ether has been strongly advocated as a disinfectant in certain abdominal operations and treatment. There are many disinfectants which are powerful enough under certain favorable conditions, or when thoroughly adapted.

Soap is one of the most valuable agents in the elimination of bacteria. It is a cleanser, and surgeons are coming more and more to the idea that cleansing is of extreme importance, as well as disinfection. If cleansing can be done at the same time as disinfecting, or just before, then disinfection will be doubly effective. But if the disinfectant is put on over a coating of dirt or grease, it is of little value. Soap, hot water and a nail brush will do a great deal toward absolute disinfection of the hands. Soap alone has some disinfectant properties but its chief value lies in its cleansing action.

CHAPTER V.

INFLAMMATION.

By LeROY M. S. MINER, M.D., D.M.D.

Inflammation may well be called the cornerstone of Pathology, for an accurate conception of the principles involved in the phenomena of inflammation is necessary in order to have a foundation upon which to build a knowledge of general pathology.

Inflammation in its various forms is so exceedingly common that without a knowledge of the changes that take place one cannot hope to understand the manifestations which occur in diseased conditions.

Definition.—Inflammation may be described, in a word, as a response or reaction to an irritation or injury. Its *purpose* is twofold:

1. To counteract or neutralize the agent causing the injury.
2. To repair the injury produced.

Thus it is seen that inflammation is intended to be a building up process; a beneficial effort of nature to repair damage. Unfortunately it not infrequently happens that under unfavorable conditions it becomes distinctly destructive instead of reparative.

Classification.—The many types of inflammation have been classified in various ways. The terms most frequently used, however, are (1) acute and (2) chronic.

It may also be classified according to the *location. Catarrhal inflammation* affects the epithelial structures, especially the mucous membranes; inflammation is said to be *Interstitial,* when the connective or supporting tissues are involved; or *Parenchymatous,* when the functionating cells of an organ are attacked.

Inflammation has also been described as *Ulcerative,* when there is loss of tissue by necrosis or gangrene; *Exudative,* when the process is characterized by unusual exudates as in pleuritic effusion; *Suppurative,* when the inflammation ends in suppuration or the formation of pus.

While these classifications help to describe the location or the type of inflammation, and while the clinical aspects may vary somewhat, it must be firmly borne in mind that the phenomena of the reactions which take place are essentially the same in all forms. The location of the injury will determine to a considerable extent the effect, but the reaction is fundamentally the same.

Inasmuch as the circulation of both blood and lymph plays a very important role in the phenomena of inflammation, it is necessary to have some knowledge of the normal circulation and also some idea of the simpler tissues which may be affected before studying the process itself.

The Normal Circulation.—The circulation of blood differs in each of the three types of vessels.

In the *arteries*, which carry the fresh red blood, the flow is intermittent, the red blood corpuscles flow in the center of the vessel (axial core), while between them and the vessel wall is a colorless zone called the plasma zone. The white blood corpuscles travel in this zone and travel much more slowly than the red corpuscles.

In the *capillaries*, or the intermediate vessels, the blood flow is slow and continuous. There is no plasma zone.

The flow in the *veins* is continuous and slower than in the arteries. The plasma zone is present, but less sharply defined than in the arteries.

The Constituents of the Normal Blood.—The chief constituents of the normal blood are eight in number, as follows:

I. Red blood corpuscles, erythrocytes.
II. Blood platelets.
III. Polymorphonuclear leukocytes (leukocytes with many nuclei).
IV. Endothelial leukocytes.
V. Lymphocytes.
VI. Eosinophiles.
VII. Mast cells.
VIII. Blood plasma.

Groups III to VII are various types of white blood cells.

The *red blood corpuscles* are bell- or cup-shaped masses of cytoplasm containing no nucleus. One cubic millimeter of blood under normal conditions contains 4,500,000 to 5,000,000 red corpuscles and at birth about 6,000,000. These corpuscles are not permanent cells, but are short-lived. Their function is the carrying of oxygen, which forms a loose combination with hemoglobin, which is the most important constituent found in the protoplasm of these cells. The red blood corpuscles are derived from the erythroblasts of the bone-marrow.

The *blood platelets* are round or oval disks about one-half the size of the red blood corpuscles. One cubic millimeter contains 250,000 to 500,000 platelets.

The *white corpuscles* grouped together are present in much smaller numbers than the red blood corpuscles, there being only 8000 per centimeter on the average. There are about 600 red to 1 white corpuscle.

The *polymorphonuclear leukocytes* are the most frequently found white corpuscles and form 70 to 72 per cent. of the total number. They are larger than the red blood corpuscles. Under the microscope the nucleus of this cell attracts attention. The nucleus is irregular and has rounded lobules. The cell membrane is sharply defined. These cells are formed in the bone-marrow also.

Endothelial leukocytes or *mononuclear leukocytes* are larger even than the polymorphonuclear cells, being two or three times as large as the red blood corpuscles. In number they make up only 2 to 4 per cent. of all the white cells. They are derived from the endothelial cells lining the bloodvessels.

The *lymphocytes* are found most frequently next to the polynuclear cells. They form 22 to 25 per cent. of all the white corpuscles. They are about the size of the red corpuscles. The appearance is characteristic. The cells are round and they take the stain well, especially the periphery. Lymphocytes are produced in lymphoid tissue and especially in the lymph nodes.

Eosinophiles make up 2 to 4 per cent. of the total leukocytes. The nucleus is frequently shaped like a horseshoe, and the cell itself may be larger than the polynuclear leukocytes. It derives its name from the intense staining with eosin. They are derived from bone-marrow.

The *mast cells* make up but five-tenths of 1 per cent. They are also derived from bone-marrow.

Blood plasma is the fluid part of the blood and contains fibrin, which plays an active part in the phenomena of coagulation. With the fibrin removed the plasma is called serum.

In addition to this brief study of the blood and its circulation it may be well to mention some of the basic histological structures which are concerned in the study of the inflammatory process. They are as follows:

I. Connective tissue (fibroblasts).
II. Endothelial cells.
III. Nerves.
IV. Lymph vessels and spaces.
V. Bloodvessels.

Connective Tissue.—The function of this tissue, as the name suggests, is to bind or support other tissue. The cell of which it is formed is called the fibroblast. These cells, as a rule, are flat, elongated cells with oval nuclei. The fibroblast frequently plays an important part in inflammatory processes.

Endothelial Cells.—These cells line the blood and lymph vessels. In form they are flattened and have an oval nucleus.

The inflammatory process may be divided into three parts:

I. The injurious agent or the cause.
II. The injury done to the tissues.
III. The resulting reaction to the injurious agent and to the injury.

The Injurious Agent or Cause.—Some writers have classified the causes of inflammation under two headings:

1. The predisposing cause.
2. The exciting cause.

As a *predisposing cause* of inflammation age may be mentioned. In growing children, the nutritional and developmental changes predispose to inflammation of the mucous membranes. The frequency of stomatitis in children is an example. In old age the lowering of the resistance predisposes to the inflammations of bacterial origin. Bronchitis is an example. Fatigue and worry are said to be predisposing causes. Any condition that lowers the natural resistance may be regarded as a predisposing cause.

The *exciting cause,* or the active injurious agents may be divided into three groups:

I. Mechanical: cuts, blows, foreign bodies.

II. Physical: heat, cold, sunlight (sunburn), electricity, x-ray, radium.

III. Chemical:

(*a*) Inorganic compounds: acids, alkalies, poisons.

(*b*) Organic: microörganisms, bacteria and their toxins.

This last group, especially the bacteria, form the chief cause of inflammation. In fact, so common is bacterial invasion the cause that it has been incorrectly assumed that inflammation was dependent upon bacteria or their products. As a matter of fact the lesions produced by the injurious agents other than bacteria are identical to those of bacterial origin.

It is not necessary to go into great detail regarding the bacteriology of inflammation, but some of the more common bacteria may be briefly described. The three most common organisms are the Staphylococcus pyogenes aureus, Streptococcus pyogenes and the pneumococcus.

The staphylococcus is found on the skin, or in the mouth, and is very common. It may possess little or no virulence, or it may become extremely pathogenic when abnormal conditions exist. It is the most frequent organism found in pus. It is a small, round cell and tends to form in groups or clusters. When grown artificially it produces a distinctly yellowish color in the medium.

The streptococcus is a more dangerous organism, but it is not so common as the staphylococcus. It is not infrequently found in the mouth and nose. It is often found in suppurative conditions with the staphylococcus. It is a spherical organism which has the characteristic of growing in chains.

The pneumococcus is found frequently in inflammatory conditions. It is said to be a normal inhabitant of the mouth. Morphologically these organisms appear like elongated cocci and tend to grow in pairs or short chains. Under some conditions a well-defined capsule is seen. This organism has been found very frequently in the inflammatory conditions of the alveolar process, commonly known as pyorrhea alveolaris. The Bacillus pyocyaneus, typhoid bacillus, colon bacillus and tubercle bacillus are other notable examples of pathogenic bacteria which produce their more or less characteristic inflammations.

The action of an injurious agent may be severe or slight, brief or prolonged. The effect varies accordingly. Some agents produce a lesion very quickly, others only after acting over a long period of time. The action may be local or general: local, as in the case of a blow; general, as in the case of diphtheria toxin.

The Injury.—*Definitions.*—*Injury* is the term applied to the changes produced in tissues and organs by harmful agents.

Lesion is the term applied to any structural change in tissues and organs, no matter how produced.

Necrosis means death and may be used to indicate death of any tissue, or of a single cell.

It is possible for injury to have been done without being able to demonstrate it. In tetanus and rabies it may be impossible to demonstrate any morphological change, even though the reaction is most violent. Thus it is seen that inflammation is not necessarily a local reaction.

The Reaction.—The *reaction to an injurious agent* is the most interesting. This reaction naturally varies very considerably, and this depends on the amount and nature of the injurious agent and on the severity of the injury. It may be evidenced in three ways:

I. By chemical changes, as alteration in secretion or excretion.

II. By morphological changes, as the presence of serum, fibrin and proliferated cells.

III. Physiologically, by alteration in functional activity.

As already stated, the *object of the reaction* is to get (*a*) rid of the injurious agent, if it is still present; (*b*) to neutralize its action; and (*c*) to repair the injury which has taken place.

The chemical and physiological changes are usually less prominent than the morphological changes. The changes in the blood following poisoning by illuminating gas is a good example of the chemical change. The convulsions produced in poisoning by strychnine illustrate the physiological changes.

Inasmuch as the morphological changes are most frequently seen and have been the most thoroughly studied, this phase of the subject can be studied to advantage.

The *morphological changes* (which are partly chemical) which take place in tissues following an injury are as follows:

I. Circulatory disturbances.

II. Inflammatory exudation.

The Circulatory Disturbances.—These occur in the following order:

1. A momentary spasm in the bloodvessels, when the irritant first acts.

2. Dilatation of the vessels with a more rapid flow.

3. The vessels still further dilate and become engorged, but the flow decreases, and may even stop in some of the capillaries and veins. The leukocytes become attached to the walls of the veins.

4. The transmigration of the leukocytes.

These cells, especially the polynuclear form, have been called the soldiers of the blood, for they rush to the seat of injury and slowly but surely pass through the vessel wall into the tissues (ameboid movement) and invade the masses of bacteria, or surround the irritant if non-bacterial, and attempt to destroy them. These cells themselves are killed in great numbers by the actions of the product of the bacteria, namely, the toxins.

The endothelial leukocytes appear later in the inflammatory process, when the polynuclear forms are diminishing in number, acting as a sort of reserve guard. They accumulate to counteract the toxins of the bacteria and to attend to foreign bodies, carbon and free fat. These cells destroy certain forms of bacteria by enveloping them in the cell structure. *Phagocytosis* is the term used.

The lymphocytes are seen most abundantly after the inflammation has existed for some time, and are quite characteristic in what we know as chronic inflammation.

Symptoms of Inflammation.—While these changes are taking place in the tissues, certain symptoms of the inflammatory process have appeared, of which the patient is very conscious. These symptoms are four, to which a fifth is sometimes added. They have been called the *cardinal signs* of *inflammation* and are classic. These are: Rubor; calor; tumor; dolor; the fifth, functio læsa; translated these are: redness; heat; swelling; pain, and impaired function.

1. The *redness* is due to the increased flow of blood. *Hyperemia* is the term that is sometimes used to distinguish the early stage of inflammation. As the flow begins to decrease, the color begins to become bluish in appearance.

2. The local *heat* at the site of the inflammation never exceeds the temperature of the internal organs, although it may be above the normal temperature of the part. No heat is produced in the affected area. The increased temperature is due to the increased rapidity of circulation and to the increased volume of blood.

3. The *swelling* is produced by the exudation from the blood-vessels.

4. The *pain* is due to pressure on the nerves by the exudates. It is often possible to count the heart beat by the exacerbations of pain. The pain is most severe in dense structures, especially when the inflammation is confined in bony walls, as in the pulp of a tooth. This pain is sometimes referred to a point distant from the seat of trouble, as, for example, earache in case of pulpitis.

5. The *disturbance of function* is especially seen in the effect on secretions, which many times are prevented or suppressed. Also movement may be limited, as seen in stiffness in a joint that is inflamed.

The Inflammatory Exudate.—Associated with or following closely after the transmigration of the white cells, there is an *exudation* of *lymph* from the lymph vessels, the purpose of which is to neutralize or to reduce the chemical activity of toxins given off by bacteria or other products present in the tissues. The exudation of lymph is seen, as an illustration, in a mosquito bite. We have here a chemical poison, and we get all the changes incidental to inflammation. That is, the change in the circulation; the increase in rapidity, then the slowing down of the blood stream, the transmigration of the leukocytes, and finally the throwing out of lymph. This is a small inflammation, but it has all the phenomena of a more extensive one.

If at this point, the most important purpose of the inflammatory reaction has been accomplished, namely, to counteract or neutralize the agent causing the injury, the inflammation subsides, the early products of the inflammatory process are absorbed and the tissues soon return to a normal condition.

Unfortunately, however, especially where bacteria are concerned, nature is not always successful, and other phenomena appear. Further exudates are thrown out; the exudation becomes more complicated, and other substances besides the lymph are thrown out. These *exudates vary* under different conditions.

Types of Exudation.—I. *Serous exudation* is watery in consistency, and is quite similar to lymph; in fact, it resembles it very closely, and some writers simply regard the serous type as an unusually free exudation of lymph. In this form the lymph spaces are particularly involved and the swelling is known clinically as *edema*. This is seen sometimes in a sprain. Pressure with the thumb or finger over the swollen area will usually leave an indentation, where the serum has been forced out of the tissues by the pressure. This indentation gradually disappears as the pressure is removed and as the serum flows in again.

Another example of this serous type of exudate is a blister from an ordinary burn, or from irritation, or friction.

II. *Fibrinous exudation* consists of leukocytes and the formation of fibrin and occurs most characteristically in the form of a membrane. A good illustration of this is the membrane formed in diphtheria.

These membranous exudates vary in their characteristics. Some are firmly adherent to the underlying tissues, while others may be readily peeled off, leaving sometimes a bleeding and sometimes a smooth surface.

III. *Suppurative exudation* is the most frequent and most important form, and is characterized by the formation of *pus*. This is the most common ending of acute inflammation, especially when bacteria are acting as the injurious agent.

In the discussion of inflammation caused by bacteria, it was shown that leukocytes were clustered together and the lymph had been thrown out. What is the next phenomenon to appear? It is briefly that the large number of leukocytes which gather in the tissue form an impairment of the nutrition of the tissue in which they are located; and we are so made up economically, so far as our tissues are concerned, that the nutriment supplied to the tissue is not sufficient to nourish the tissue itself and also these leukocytes, with the result that the tissue cells themselves lose their vitality; and then, also, the leukocytes in giving battle to the bacteria are destroyed in large numbers, either by the bacteria or their toxins. This lack of nutrition, this dying of the tissue cells in which the inflammation is located, and the death of the leukocytes themselves, cause a dissolution of the tissue, and as a consequence there is a cavity filled with dead leukocytes, dead tissue cells, lymph, and dead and living bacteria, which forms a creamy fluid called pus. Clinically this is known as an *abscess*.

The formation of an abscess marks the end of the inflammation, so far as the tissues themselves are concerned; that is, the inflammatory process has been limited and localized.

The leukocytes which transmigrate into the tissues entirely surround the seat of injury and *form a protecting wall* against further invasion.

If it were not for this action of the leukocytes in forming this wall between the general circulation and the injurious agent in the form of bacteria, each time we received an injury infectious in its nature, that is, of bacterial origin, we would either have a general blood poisoning because injurious products would be taken up by the circulation, or the inflammation would extend indefinitely out into the tissues until our bodies were wholly consumed by the inflammation. Therefore this formation of an abscess, while disagreeable, painful and uncomfortable, in itself is an excellent thing, because it prevents the disturbance from becoming a general one of very serious consequences.

Occasionally the leukocytes are unable to control the local action, or perhaps the infection began in the circulation, and in that case general blood poisoning or *septicemia* results. This is a very serious condition. But, fortunately, the leukocytes generally form an actual resisting force, or limiting membrane, through which the bacteria are unable to pass and inside of which is this pus cavity.

The next question that naturally arises is, what becomes of the pus and this wall of leukocytes? The tendency of all abscesses is to evacuate themselves; that is, to throw off their contents, and get rid of the secretion that exists. The method of doing this is as follows: the fluid elements of the abscess cavity, or the pus, increases in amount, and the increase in quantity increases the pressure around the tissues, and as this fluid element continues to increase, the pressure becomes greater and greater, and as the pressure becomes greater the tissue before it gradually yields, and the pus finds its way in what has been classically called the *path of least resistance*. This act of nature in endeavoring to throw off the pus has been called the burrowing of pus. It tries hard to get through to the surface of the body, or to a cavity, and burrows its way through the tissues in the path of least resistance. When the pus has finally approximated the surface, we have what is known as *pointing*. This term is well known. Years ago it was customary to poultice any inflammatory condition to bring, as they said, the trouble to the surface, and this poulticing was intended to hasten the action of the pus burrowing, to hasten the pointing of the abscess so that the contents could be evacuated.

If an abscess is not surgically opened and the pus discharged, the tissues will spontaneously rupture and the pus will escape, either on the surface of the body somewhere, or else into one of the cavities of the body, as has been suggested. For instance, if an abscess on the lower jaw results from an inflamed tooth, the path of least resistance may be downward and a large swelling occurs under the jaw. As the pus comes closer and closer to the surface it either is opened and evacuated surgically, or else it may point and discharge underneath the chin. If there is an abscess, for instance, in the appendix, and it is allowed to go uncared for until it ruptures, it ruptures into the abdominal cavity, and peritonitis results. The pus, in other words, tries to escape from the tissue and come out freely, and thus relieve the pressure on the tissues in which the abscess has formed.

The channel through which the pus passes is called a *sinus,* and the opening on the surface is called a *fistula.* These two terms are very common, especially in inflammatory conditions connected with the mouth and teeth. We speak of a sinus, for instance, when a chronic abscess discharges into the mouth over a tooth on the gum. The canal or channel through which the pus escapes to the surface is the sinus, and the opening on the gum out of which the pus comes is the fistula.

If the abscess is a very superficial one, it is merely a simple abscess of the skin. When the pus comes through the surface the layers of the skin may be destroyed, leaving more or less of an open wound of a very superficial nature. This condition is known as an *ulcer.*

Chronic Inflammation.—Before discussing repair or what takes place after the pus is evacuated, chronic inflammation may be briefly described. *Chronic inflammation* is the *result* of a *continued irritation.* It may follow acute inflammation, or it may start as inflammation of a chronic form. Chronic inflammation is a very different process from the acute form, and some writers have gone so far as to say that chronic inflammation is not a true inflammation at all. The essential feature of chronic inflammation is the formation of new connective tissue, a proliferation of the fibroblast, or connective-tissue cell. The term fibrosis has sometimes been applied to this form of tissue change, because it describes the condition better than the term chronic inflammation.

In this chronic inflammatory process, hyperemia, or change in the bloodvessels, that is, the bringing of additional blood to the part, edema, the throwing out of the lymph, and suppuration, the formation of pus, are absent. Instead there is this proliferation, as it is called, of the connective-tissue cell, and the throwing out of some of the white cells of the blood, particularly the lymphocyte. The *chief characteristics,* then, are the formation of connective tissue, the fibroblastic proliferation, and the lymphocytic infiltration or throwing out of these lymphocytes. No pus is found nor other symptoms of the inflammatory changes.

Repair.—Repair is the general term used to describe the processes taking place after injury and exudation caused by harmful agents. The repair of tissue or the repair of the injury is a very complicated subject but it includes three divisions which will be briefly described:

First, repair includes removal of foreign bodies of all sorts; and by foreign bodies is meant dead cells of all kinds: (1) tissue cells that have died as the result of the process, (2) leukocytes of the polynuclear form, (3) endothelial leukocytes, (4) bacteria dead and alive.

The absorption and removal of foreign bodies such as sutures should also be included. There may be an operation and stitches are taken deep in the body. These stitches are allowed to stay there, and they are removed as foreign bodies, and this is part of the function of repair. In addition, secretions from bacteriological products, the toxins, and in some cases the lime salts which are formed as the result of the various conditions are included; in fact, the removal of anything that is foreign, or is not of service in the tissue is one of the functions of repair.

Second, the organization of fibrin.

Third, the regeneration of cells to restore the part which has been destroyed.

I. How does the removal of the foreign bodies take place? In a word, the leukocytes, or white cells, change somewhat their function, and they become active in carrying off the foreign bodies.

These dead tissue cells are destroyed and removed inpart, a little at a time. The bacteria may be actually digested by the leukocytes after being taken up by these cells. Very frequently under the microscope these endothelial cells may be seen with several bacteria in their protoplasm. The endothelial leukocyte is especially active in this part of the process. The phenomenon is called phagocytosis.

II. The fibrinous exudate is taken care of by the connective-tissue cells, the fibroblasts, which form and grow into the fibrin and gradually replace it.

III. The regeneration of cells is the growth of new cells, and is brought about by what we know as cellular division, or mitosis. Under stimulation, the cells in the vicinity of the wound will gradually begin to multiply and fill in the vacancy that is caused by the destruction of the tissue, and gradually this cavity or the injury due to the loss of tissue is replaced by new cells, which have divided and redivided and divided again.

Clinically speaking, repair or the healing of wounds takes place in two ways: first, by primary healing, as we know it, called *healing by first intention;* and, second, by secondary healing, or *healing by second intention,* or healing by granulation tissue.

Healing by First Intention.—To illustrate the healing by first intention, let us assume we have an incised wound. After the bleeding is stopped the wound, which is the result of a cut, remains filled with blood, and this blood coagulates and forms a sort of plug in the wound. This plug or coagulated blood retracts and tends to hold the edges of the wound together, and over the surface a crust is formed, which is nothing more than dried secretion, dried lymph plus a few cells, and this is commonly spoken of as *scab*. The healing process begins at once. Of course, the various stages of inflammation, the changes in circulation, and throwing out of the leukocytes must occur, but all of the cardinal symptoms of a true inflammation may not be present. In addition to the throwing out of the leukocytes, the connective-tissue cells become active; and this blood-clot, which has been mentioned above, acts as a sort of scaffolding, upon which the connective tissue builds, sending out little prolongations of tissue. This connective tissue gradually replaces the blood-clot and the edges of the wound are held firmly together. Then if the wound is on the surface, the epithelial coverings will send out prolongations and heal it over with no evidence of scar. If the edges of the wound after a cut are held firmly together, for instance, with plaster or a bandage, very little connective tissue is formed. It takes very little new tissue to repair the wound; but if it is a gaping wound, more material is needed to repair it; and where a portion of the surface of the skin is lost and it becomes impossible for the epithelial cells to span the breach, the connective tissue fills it in, and the result is known as a *cicatrix*. The tissue which forms is called cicatricial tissue, or *scar tissue*. This has a very great tendency to contract. As these new cells become older they contract somewhat, and the contraction of scar tissue is well known. The scar tissue that results where the epithelium is not completely restored, for instance, on the hand, is not original skin tissue, but it is made up of connective tissue.

Healing by Second Intention.—It has been shown that healing by first intention has nothing to do with infection; that is, bacteria have been absent in the changes that have taken place. In repair, by second intention, however, the suppurative process, and all the phenomena of inflammation with the formation of pus and the evacuation or throwing out of pus cells, and the products of exudation must occur before the actual healing. When this takes place, the cavity which results from the pus is filled in gradually by granulation tissue and connective tissue in much the same way as in healing by first intention; but there is much more tissue to be restored, and the healing process may be slow, particularly if the cavity is large. It is often possible, after the pus has spent itself and the acute symptoms have subsided, to bring the edges of a wound together and have it heal by first intention, but that is not customary. If instead, in this type of wound the opening is packed with gauze, and allowed to fill in, as we say, from the bottom, the granulation tissue fills up gradually, and each day less gauze is used in the packing until the cavity is filled in solidly with this connective tissue. This healing by granulation becomes very important under some conditions, because the contraction is sometimes excessive. If there is a bad inflammation or a bad abscess of the cheek, for instance, or the cheek muscle and the wound has to be repaired by second intention, or by granulation healing, after a while this contraction of the cicatricial tissue may be so great that the person is unable to extend the lower jaw, or open the mouth as wide as desirable, and it becomes a very serious condition under some circumstances. Fortunately, this state of affairs is not very common.

Repair then in general is the effort of nature to restore the tissues to the normal after an inflammation; and when the repair is complete, especially if it is by first intention, the parts have been restored to function and the tissue cells resume their normal relations.

NOTE:—In this discussion, liberal use has been made of the masterly exposition of the subject by Prof. F. B. Mallory, to whom the author is deeply indebted.

CHAPTER VI.

DEPOSITS AND ACCRETIONS UPON THE TEETH.

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The factors involved in the composition and mode of production of deposits and accretions upon the teeth are those which are intimately connected with the chemistry, physiology and pathology of the saliva, the study of which is perhaps one of the most important considerations both in its scientific and practical aspects, that is engaging the attention of the dental profession, for it is through the study of saliva that we hope to ultimately solve some of the most important problems with which we have to deal in dental practice.

It has been mainly through the study of the saliva that we have arrived at some very definite ideas as to the causation of dental caries, that one disorder, the prevalence of which has really created the dental profession; and through the study of saliva we have also learned something of various other diseases to which the teeth and soft tissues of the mouth are subject, and further, we hope to learn something through the study of the saliva about the deposits or accretions that are commonly spoken of as tartar and about their mode of formation. After all, there is no phase of dental practice that is of more immediate importance to those who are pursuing this course than the causes which lead to the formation of these deposits upon the teeth.

As for the word "tartar," some years ago in one of the popular magazines there appeared an article by a physician who stated that the tartar on the teeth was called "tartar" because it consisted of tartrate of lime. An eminent professor of chemistry once said to his class during a lecture that he never had understood why the sulphate of iron was popularly called copperas. He said he imagined it must have been called copper by the Dutch, because it had no copper in it. By the same mode of reasoning, it is probable that this medical man called these deposits tartar because there is no tartaric acid in them.

The term tartar was applied by the alchemist Basil Valentine to the deposits called argols in wine casks consisting essentially of potassium tartrate, and the acid derived therefrom was called tartaric acid or the acid of tartaros. Paracelsus applied the term much more widely to include earthy deposits from animal fluids such as calculus from the saliva. Tartar consists essentially of calcium phosphate or phosphate of lime and some carbonate of lime and corresponding magnesia salts held together by a binding material that we call mucin, a substance derived from the mucus of the saliva; that and some organic matter such as food particles, the bodies of dead or dying bacteria, make up the bulk of what we call "tartar."

In order to understand the formation and deposition of tartar we must first know something about the saliva. By saliva we mean that mucoid fluid which we find in our mouths from time to time. It is not always flowing, but our mouths and our food are lubricated and moistened by it. This saliva is manufactured by three pairs of glandular structures situated in the region of the mouth which pour their secretions into the oral cavity. The secretions of these several pairs of glands, which we speak of as the salivary glands, differ in their composition. Neither do all of these glands pour their secretion into the mouth at the same time, but under different circumstances and in response to different kinds of stimuli, namely, the stimulus of food or the stimulus of the thought of food or the stimulus of pain.

You are all familiar with the common expression that if we think of this or that kind of food it makes our "mouths water." This is literally true. Under the psychic stimulus of the thought of food, especially of food which is sapid or tasty, the salivary glands are encouraged to pour their secretions into the mouth, but it is interesting to note that different kinds of foods excite the secretion of different glands. For example, the physiological chemist Pavlow, of St. Petersburg, found that when a piece of fresh meat was offered to a dog the flow of saliva from the sublingual and submaxillary glands was stimulated, but not that from the parotid, which is a large gland situated in front of the ear.

When dry food, like powdered meat, was offered to the dog, the parotid salivary secretion was stimulated. So under different stimuli we find a response from different glands, and the response seems to stand in very close relationship to the character of the food that exerts the stimulus. This is an important relationship too, because dry foods, for example, need a great deal of moisture for two reasons: first, for converting the food into a bolus so that it may be swallowed; second, for furnishing sufficient water to the food in order to dissolve its soluble elements and to give taste to it. Tasty things stimulate the flow of saliva, and the watery secretion of the parotid gland is necessary in order to dissolve what is soluble in the food in order to bring out its taste. We cannot taste anything unless it is soluble, no more can we smell something unless it gives off a vapor of some sort. So that gratification of the sense of taste is secured by the solvent action of the parotid saliva, mainly, upon the foods that we take into the mouth.

Besides the secretion of the salivary glands, the secretion of innumerable mucous glands that are imbedded throughout the whole oral or buccal mucous membrane, the lining membrane of the mouth, is added to the mixed saliva, and it is the secretion of these mucous glands that give to the saliva its slimy or slippery quality, owing to the substance mucin contained therein.

Mucin is a very important constituent of the saliva, and among other things has a very direct bearing upon tartar formation, but its main function seems to be that of a lubricant. Perhaps you all know of the peculiar technic of reptiles when they feed. A boa constrictor for instance, kills its prey, which may be a half-grown pig, and covers it with a slimy coating so as to lubricate this relatively enormous mouthful, and to render its passage into his interior as easy as possible. In a minor degree, the same function is performed by the lubricating exudate of the mucous glands of the mouth upon the bolus of food in the mouth of the human being.

Beside this important substance, mucin, the saliva contains also a peculiar ferment known as ptyalin, the function of which is to begin the digestion of starchy substances in the mouth. Starch as such is not utilizable as food by the body, therefore the ptyalin acts upon it, converting it by degrees into a kind of sugar, maltose. This predigestion of starch, or preparation for intestinal digestion, takes place in the mouth, hence the very great importance of thorough mastication of starches, which is doubtless the main justification for the fad of super-chewing that has spread over the country under the name of Fletcherism.

Another constituent of the saliva, though perhaps it is not of very great importance, has been exciting a great deal of comment in the past four or five years; that substance is known as potassium sulphocyanate, ordinarily spoken of as sulphocyanate. It may be questioned that it is a potassium sulphocyanate, but some kind of sulphocyanate is present which is possibly a sodium or ammonium sulphocyanate. It has the peculiar property that when to a small quantity of saliva a drop or two of a test solution of perchloride of iron is added, if the sulphocyanate is present it causes a red or reddish coloration of the saliva. This is rather a striking reaction which can be made very easily by simply taking a few drops of saliva, a half-thimbleful, adding to it a drop or two drops of the ordinary tincture of chloride of iron, and if sulphocyanate is present in the saliva, a red color will result. This reaction is rather dramatic, and has caused a great deal of discussion and debate as to its significance which thus far appears to be unimportant.

Sulphocyanate was at one time supposed to have a very important bearing upon caries causation, or of the prevention of carious action in the mouth, but recently it has been pretty definitely shown that sulphocyanate is an incidental constituent of the saliva, and that it has no very important significance except as a waste product of nutrition related to some other chemical activities in the body.

In addition to the constituents mentioned, saliva collected in a receptacle will show certain sediments, solid matter, if it stands for a short time. The salivary sediment consists mainly of the desquamated or peeled-off external epithelial cells. Just as the scarf-skin, or outer layer of the cuticle, separates from time to time, so does the mucous membrane of the mouth shed its epithelial coating into the saliva, and we find mixed with the saliva these epitheilial scales from the buccal mucous membrane which when a specimen of saliva is allowed to stand for a time separate as sediment.

We find also as corpuscular elements, the leukocytes, or white blood corpuscles, which gain their way into the saliva changing their form somewhat. They have been spoken of as salivary corpuscles, but they are really white blood cells which have undergone certain changes of form.

As to the further chemistry of the saliva, if we take a measured quantity, and evaporate it to dryness, we find a small residue of solid matter. This residue consists of two kinds of substances, certain mineral salts which we speak of as the inorganic constituents of the saliva, and another kind of solid matter which is organic in character.

The total solids of saliva vary considerably in amount. It is difficult to say what represents the total quantity of solids in the saliva, but it is extremely small in amount, from about half of 1 per cent. to possibly 1 per cent. of the total saliva. These are only approximate figures, because the composition of the saliva varies constantly, depending upon the time of day when the sample is taken, how closely to a meal, whether after vigorous prolonged chewing, after drinking large quantities of water, or after abstaining from water for some time. Saliva becomes more concentrated the less water we drink, and it becomes more dilute in accordance with the quantity of water drunk. The total amount of solids in the saliva, being variable, is therefore rather difficult to state.

The normal saliva in the ideally healthy individual, who has no caries of the teeth, no deposits upon the teeth and in whom the various functions are properly performed, the individual who is living up to the highest state of physical efficiency, in such a normal human being we can safely say the saliva is colorless, odorless, and tasteless.

If the saliva develops either an odor or a characteristic taste, or a color, something is wrong, it is not a normal, but a pathological saliva, something has gone wrong with the individual, the chemistry of his body is not working properly.

When studying the physical appearance of a quarter- or a half-ounce of saliva collected in a test-tube, we find that in addition to its limpidity, its clearness or opalescence, a slight slimy quality due to the mucin and the presence of sediment, there is a covering of froth upon the top in which air is entangled. Besides which the saliva contains dissolved within itself a certain quantity of carbon dioxid. As we give off carbon dioxid from the lungs, so carbon dioxid is present to some extent in the saliva, and it gradually escapes on standing; hence the saliva in the test-tube soon loses its froth, the sediment settles to the bottom, and we have a column of this clear, odorless, tasteless substance above a layer of whitish sediment.

Any variation from these general conditions indicates ill health of some sort, or some error in nutrition, and the saliva is so sensitive, chemically, it reflects the variations in composition of the blood stream so accurately that we can utilize it for the study of the nutritional condition of the individual at the time when the specimen is taken.

It is a familiar fact that physicians have for years been studying the urine and the blood, as means for determining the condition of bodily nutrition, but investigation has brought forth the fact that the saliva is almost as important an index of the condition of nutrition for the time being as either of these other fluids mentioned.

When the saliva is poured from the glands into the mouth it comes into an entirely new environment, that is to say, as it issues from the gland it is, comparitively speaking, sterile; it is not infected with bacterial elements, we do not find the bacteria in the saliva as it issues from the glands, but it issues into a cavity that is infected on all surfaces; in fact, it is poured into that portion of the human anatomy which is the portal of entry, for nearly all of the bacterial organisms that enter the body, and the saliva is necessarily subjected to the influence of these microörganisms.

The organisms that infect the mouth are not only myriad in number, but they are of an infinite variety and they produce different effects upon the saliva. Let us consider a little more closely the nature of that action in general. It is a familiar fact that if a quantity of milk, for example, is exposed to the atmosphere for a sufficient length of time, especially on a reasonably warm day, the milk in the course of time undergoes changes and becomes sour, as we say. First, it develops a sour taste, then becomes curdled, and if it is left to stand still longer the sourness disappears and it becomes putrid, developing a very disagreeable odor, as it undergoes decomposition. Modern bacteriology has settled the nature of these processes. They are processes of decomposition or of tearing apart of the various complex compounds that we find in milk into simpler substances.

Milk contains sugar, nitrogenous or proteid matter in the form of cheese, or casein, it contains water and fats. Each one of these substances seems to have a selective quality for certain kinds of bacteria, some of which attack the sugar, for example; others will only attack the caseous portion, the curd of the milk; other germs attack the fat. Butter, for example, when it becomes rancid, forms a particular kind of acid, butyric acid, as it is called. As the sugar element in the milk undergoes decomposition, it becomes sour just as the sugar in cider is converted into vinegar, or alcohol, as the case may be, through the agency of bacterial action.

Upon the same principle these various substances in the saliva, mucin, animal matter, and sometimes sugar, which is formed by the action of the ptyalin upon starchy matter in the mouth are decomposed by the activity of certain special kinds of bacteria and produce what are designated in chemistry as typical or characteristic kinds of end-products, for example, acid substances; or they may produce ill-smelling substances, hydrogen or ammonium sulphide due to putrefaction or substances like ptomains or toxins which have a specific poisonous action upon the tissues with which they come in contact.

Incidentally caries or decay of the teeth is produced the same way. Thus we see the importance of the study of the saliva in relation to the manner in which it is decomposed through the agency of bacteria. From all this we may also deduce the immense importance of a clean mouth, not only as regards the integrity of the teeth and the tissues about the teeth and the mouth itself, but as related to the general health of the individual. The question of a clean mouth is not a matter of sentiment alone, or a matter of aesthetics, but it is fundamentally a question of health.

Since decomposition of the saliva is brought about through the agency of a large variety of bacterial forms constantly inhabiting the mouth, and since the end-products of this bacterial action are so varied, and in most instances either poisonous, or capable of exerting corrosive action upon the tooth structure, it is evident that the best time to get rid of the conditions which result from these fermentative and putrefactive processes that take place in the mouth, is at the beginning, and that by doing so we can successfully prevent not only diseases of the teeth, but many diseases which affect the entire body.

In connection with the processes of decomposition through the agency of bacteria, a number of phenomena manifest themselves. In the first place, under certain conditions there is the production of a peculiar kind of deposit upon the teeth which has been spoken of as the bacterial plaque. The bacterial plaque is very important in many ways. In the first place, it represents the first step in the process of that disintegration of tooth structure which we call dental caries. Broadly speaking, we cannot have dental caries excepting through the agency of the bacterial plaque. Viewed simply from a physical point of view, a bacterial plaque is a deposit upon a tooth surface which localizes the process of decay. The function which the bacterial plaque performs in localizing the process of tooth decay at certain points is the factor which determines the principal characteristic of tooth decay, namely, that of cavity formation.

Let us for a moment examine the nature of this deposit called the bacterial plaque. Recall for the purpose of this argument the fact that the saliva contains first of all mucin in solution. In order to have a solution of mucin in the saliva we must have an alkaline reaction of the saliva, because mucin is not soluble in an acid fluid. If we take a specimen of saliva and add a drop of any kind of acid to it, acetic acid, lactic acid, sulphuric acid, citric acid, etc., we shall immediately see what we call a precipitate which looks as if something in the saliva had been cooked, as in the cooking of the white of an egg. That happens instantly when mucin comes in contact with any acid.

One of the acids which is most prompt to cause the precipitation of mucin is lactic acid, the acid that is produced when milk sours.

Lactic acid is instantly produced in the mouth by the action of certain forms of bacteria upon sugars found in or taken into the mouth.

Sugars, as we know, are produced in the mouth by the action of the ptyalin of the saliva which converts the starch into sugar. As long as sugar is thus formed certain classes of bacteria act upon it and split it up into lactic acid. These lactic-acid-producing organisms being constantly present, fermentation goes on and lactic acid is produced as long as there is something for the organisms to live upon. Just the moment that a point (considering a bacterium as a point) of acid production is set up in the saliva there occurs a precipitation around that point of insoluble mucin, and when the action is started by the lodgement of lactic-acid-producing organisms upon a tooth surface where they may develop and multiply undisturbed in protected locations the process continues until what we call a bacterial plaque is formed. These plaques are localized upon all tooth surfaces that are protected from the friction of food or of the tongue or lips, and in places that are not kept thoroughly polished and clean, especially in the class of mouths that are susceptible to dental caries.

It will be readily understood that the acid which is manufactured at the point localized by the bacterial plaque is constantly disintegrating the tooth structure upon which it has formed and breaking it down. Thus we have a deposit produced from the saliva and from conditions existing in the saliva which is the first step in the process that we speak of as dental caries.

The plaques are not ordinarily visible to the naked eye, but there has been introduced[1] what is denominated a "disclosing solution" containing iodin, which renders them visible. By applying tincture of iodin to mucin we secure a color reaction, that is to say, it produces a brownish or reddish-brown tint deeper than that of the iodin, especially if certain of the sugars, maltose, for example, be present. If we paint the tooth with iodin or spray it with a solution of iodin, in the course of time we will find that the iodin has stained certain portions of the tooth to a darker tint than others, owing to the fact that the plaques have taken up the iodin, combined with it, and formed a dark brownish stain. The formula of Skinner's disclosing solution is as follows:

Iodin crystals	50 grs.
Potassium iodid	15 grs.
Zinc iodid	15 grs.
Glycerin	4 dr.
Water	4 dr.—M.

As an adjuvant to the disclosing solution, however, another step or stage has been suggested by H. C. Ferris, and that is, the spraying of the surface, after it has been treated with the iodin solution, with a boiled starch solution. It should be remembered, however, that starch

[1] F. H. Skinner, Dental Cosmos, 1912, p. 43.

and iodin, no matter how they are put together, produce a very dense blue color, and unless one is careful in making this test, the starch may apparently disclose plaques where they do not exist. Hence the tooth should be rinsed thoroughly before the application of the second member of the disclosing solution is made in order to remove excess of iodin. As a matter of fact, a plaque is disclosed with sufficient clearness by the use of the ordinary official standard tincture of iodin, 7 per cent., without subsequent application of starch solution.

There may be other sources of plaque formation, but the explanation given indicates the general principle which accounts for these soft, slimy, fairly adhesive deposits upon the teeth, which can be readily rubbed off by the application of fine pumice on an orange-wood stick, if the rubbing and polishing is thoroughly and carefully done. It does not require the instrumentation that we speak of as "scaling" to remove deposits of this class.

In the precipitation of mucin by lactic acid we have the general principle involved in practically all of the deposits of that character. These may be localized or there may be a general precipitation of mucin upon the teeth, carrying with it particles of food or débris of various sorts, which, if not removed, condenses, grows harder, more tenacious, and more difficult to remove, though when first deposited it is very soft in character.

We come now to a consideration of an entirely different class of deposits which are of the true tartar type, namely, the mineral deposits upon the teeth. The formation of tartar is a most complicated process and constitutes one of the puzzles of the chemistry of the mouth. What we do know about it is this: chemical analysis of these hard deposits called tartar shows them to consist mainly of calcium phosphate, some calcium carbonate, the bodies of dead bacteria, débris of food, food particles, all bound together by mucin.

An English investigator, Mr. Rainey, about fifty years ago, undertook a study of the mode of formation of shells of various sorts, and he was lead into some experimentation with reference to the changes that take place in certain kinds of earthy precipitates like carbonate of lime under varying conditions, as for example, when these earthy substances were precipitated in a solution which contained a material like gelatin, gum arabic, or egg albumen, or what is termed in chemistry, colloidal substances. He found that the carbonate of lime was precipitated from a watery solution in a more or less crystalline character, but if the smallest quantity of glue, albumin, gelatin, or other glue-like substances, was added to the water in which the precipitation took place the deposit instead of being of a crystalline character was made up of little spherical bodies that were more or less translucent. The precipitate formed very slowly and this investigator found that these minute globular masses side by side tended to increase in size by additions to their exterior, this increase in size continuing until two of these bodies would come together and coalesce;

then another one would grow up to this mass and they would coalesce, so that gradually it assumed the appearance of a mass of marbles glued together or, of a mulberry mass.

This investigation led others to continue the observations and finally it was shown that this process of precipitation and molecular coalescence was at the bottom of a number of very important processes not only in the human body, but in the mode of growth of the shells of mollusks and the pearl formation in the oyster, for example. On further investigation it was found that the pathological conditions that involve stone-like concretions in the kidney or the bladder, concretions of a calcareous character that are found sometimes in the ear and various parts of the body, or in old abscesses that have undergone repair, all arose after the same principle of coalescence of the precipitate of an earthy salt in combination or in contact with a colloidal or glue-like basis which acted as a binding material.

FIG. 51.—Specimens of parotid tartar; actual size.

Precipitations of the earthy salts, phosphates and carbonates, that were held in solution in the saliva when they take place in the human mouth combine with the glue-like substance in the saliva which we have spoken of as mucin, and are bound together by the mucin to form the mass called tartar which deposits itself upon the teeth. Tartar varies in a great many ways; it varies in the rapidity with which it forms, it varies in the position in which it is deposited, and above all it varies in its density, the tenacity with which it adheres to the tooth surface and its toughness.

Certain classes of tartar undergo very rapid formation and enormous development. Masses of tartar weighing as much as from two hundred and fifty to three hundred grains are reported. It seems incredible that any human being could tolerate in his mouth a mass of tartar larger than a pigeon's egg attached to the buccal surface of the molar teeth, yet such instances are by no means infrequent. Tartar which is formed rapidly and in large masses is usually relatively soft and friable and can be readily removed by proper instrumentation.

Every dentist has had patients with the idea in their minds that tartar was protective to the teeth and for that reason they objected

FIG. 52.—Sublingual tartar on a lower incisor.

FIG. 53.—Sublingual tartar on a lower canine.

to having it removed. It is true to a great extent that teeth upon which that kind of tartar is deposited rarely decay, not because the tartar is protective, but because conditions that cause the deposition of the tartar are precisely the opposite of those that favor caries of the teeth

FIG. 54.—Partial denture clasped to first and second molars, which have been lost by deposition of parotid tartar.

When such enormous accumulations are removed from the teeth the patients are often surprised that the teeth do not come out.

This kind of tartar will form upon artificial dentures just as readily as upon the surfaces of the natural teeth, and it is usually found at positions opposite the orifices of the ducts of the salivary glands. For the same reason we find these enormous masses ordinarily upon the buccal surfaces of the molars and upon the lingual surfaces of the lower teeth occupying positions almost opposite the openings of the salivary ducts. (See Fig. 54.)

The question of why this is so is the chemical problem that we are confronting. This is what we know: that calcium phosphate as it exists in tartar is not the same kind of calcium phosphate that exists in solution in the saliva; that is to say, after it reaches the mouth it undergoes some chemical change, the nature of which may be illustrated as follows: One of the popular drinks advertised at the soda fountains is "Acid Phosphate." Calcium phosphate or lime phosphate, chemically speaking, is a term applied to a group of compounds of which there are two distinct kinds. One contains more lime in proportion to the phosphoric acid than does the other. The one which contains less lime in proportion to the phosphoric acid is designated as acid phosphate, which is soluble in water, and has acid properties; whereas the other phosphate which is designated as basic phosphate contains a larger proportion of lime and is insoluble in water.

If we add to the acid phosphate a little more lime, we convert it into basic phosphate; and because of its relative insolubility it would fall out of solution as a sediment or precipitate. A similar process occurs in the deposition of this phosphate as tartar in the mouth. It is in a state of acid combination in the saliva. Possibly it is the content of carbonic acid in the saliva which holds the phosphate in solution, and when the carbonic acid escapes in the saliva, the phosphate, having nothing to hold it in solution, falls down as a precipitate.

Mucin acts as a glue-like binding material to the small earthy particles of phosphate and fastens them together and when the proportion of mucin to the calcium phosphate is in certain ratio the mass may be so dense and adhesive that it is almost impossible to cut it with a steel instrument or scrape it from the tooth surface.

The escape of carbonic acid is one of the means by which we think the earthy materials of the saliva are precipitated. If we take any alkaline substance into the mouth, thereby adding free alkali to the saliva, we are likely to cause a precipitation of the lime salts.

There is always a certain amount of ammonia, produced by the chemistry of nutrition, that issues from the lungs with the expired air, and if there is enough ammonia produced in a given case to impart a definite free alkalinity to the saliva, then precipitation of the lime salts takes place or ammonia may be produced in the mouth by putrefaction, decomposition of animal substances causing tartar formation in unclean mouths.

There is another suggested mode of tartar formation. Dr. H. H.

Burchard found that when fermentation is going on in the mouth with production of lactic acid in small quantities the mucin is precipitated and the coagulated mass of mucin tends to gather within itself these earthy salts, just as a net going through a stream would gather up fish; this mass is deposited upon the teeth, and condenses more and more, forming tartar.

Tartar has been thus produced artificially out of the mouth, by taking saliva rich in calcium salts and adding small quantities of dilute lactic acid, causing precipitation when a hard material of a dark greenish shade is produced, physically similar to the deposits that we find upon the teeth.

One of the most interesting examples of tartar formation is that observed upon the teeth of the natives of Indo-China and the Malay Archipelago. They are habituated to the chewing of the betel nut. This use of the betel nut as a masticatory is very prevalent throughout Indo-China and the Malay Archipelago.

Habitual chewing of the betel nut, in the course of a short time, causes the teeth to become stained to a very dark reddish brown of about the color of the exterior of a chestnut, and enormous deposits of tartar quickly aggregate, so that the teeth become distorted in appearance and position and are very quickly lost from their sockets. It is not infrequent that young people not over twenty-five years of age are rendered completely toothless by the habit of betel-nut-chewing.

The shavings of betel nut are wrapped up in pieces of the leaf of a certain kind of plant called Penang pepper, along with some aromatic spices such as catechu or cloves, or cardamom seed, according to the taste of the betel-nut-chewer, to give it an aromatic flavor. Then about the quantity of half a small spoonful of lime, made by burning oyster shells, is sprinkled all over this mass to develop the flavor. This morsel, rolled up in the green pepper leaf, is very carefully tucked away in the cheek. It causes a free flow of saliva tinged with a red color. The addition of the lime, which develops the flavor, is what causes the trouble. The acid or soluble phosphate of lime in the saliva upon the addition of this extra lime, is converted into the insoluble form of phosphate and precipitated on the teeth. (Figs. 55, 56, and 57.)

The foregoing is an example of the formation of tartar due to change in the chemical composition of the lime salts of the saliva from a soluble form into an insoluble form.

The hardness of the tartar depends upon the amount of its lime constituent as related to the mucin constituent. The hardest formations of tartar contain more of the glue-like or mucinous element than do the more friable and easily broken-down forms. The hardest tartar formed is found just under the gum margin. The large masses that are attached to the free surfaces of the teeth opposite the ducts of the glands are usually soft and easily removed regardless of size, but the rings of tartar underneath the gum margin, the hard scales of tartar, are the most difficult of removal. It is this kind of tartar that contains the largest proportion of organic binding material, because the deposit of tartar at that point sets up an irritation of the gum tissue and causes the weeping out from the gum tissue of the albuminous, serous portion

Fig. 55.—Lower incisor almost completely encrusted with betel tartar.

Fig. 56.—Lower canine covered with betel tartar.

Fig. 57.—Upper and lower incisors lost from deposit of betel tartar. As they gradually loosened from the encroachment of the tartar they were bound together with fine brass wire by a native dentist, to give them firmness by mutual support.

of the blood which combines with this deposit and forms a very hard, tenacious mass.

Farther down upon the roots of the teeth we frequently find deposits of another form of tartar, which is probably not salivary in origin. It is spoken of as serumal tartar and is derived from the serum of the blood. From a chemical standpoint it is practically a formation of the same character but it originates differently. So far as we know, this serumal tartar which is situated deep down upon the roots of the teeth and not connected with saliva in its origin, is the result of some primary inflammatory condition upon the tooth root. It is not necessary to go into the causes of such preceding inflammatory conditions which, instead of breaking out as abscesses, have healed spontaneously by what we call the process of resolution, by which is meant that the bacteria which set up the inflammation have died. They have been killed by the resisting forces of the body itself and the inflammatory process has stopped, and the tissues have undergone repair, but the dead bacteria and the broken-down tissue constituting pus has gradually become dehydrated, and there is left a cheesy mass which later on has become saturated with lime salts derived from the blood stream itself. These lime salts combine with this cheesy mass resulting in a tartar-like formation in which the cheesy mass of colloidal organic matter takes the place of the mucin in saliva as the binding material.

Tartar formed in that way is a mechanical irritant to the surrounding tissues, making them subject to subsequent infections. The tartar acts as a foreign body in the tissue setting up irritation, infection follows and the process is repeated with continued growth of tartar, or the abscess may break at the gum margin and a pyorrheal pocket may thus be formed. The pus pockets in pyorrhea may be formed from the root to the gum margin or from the gum margin rootward.

Two other phases of this subject are of importance; one is the color of the tartar, the other is the solubility of the tartar. Tartar we find to be of different colors. The tartar which forms rapidly is soft and friable, salivary in origin and more nearly colorless than any of the other varieties. It is nearer in chemical composition to a simple precipitation of phosphate of lime. But when it forms slowly and under the margin of the gum we usually find it highly colored. It must always be remembered that tartar precipitated around the necks of the teeth is a mechanical irritant to the soft tissues of the gum region. This irritation predisposes to bacterial infection, which leads to an inflammatory process and, as the inflammation proceeds, more or less blood weeps out from the irritated tissue in contact with the tartar. The tartar is then colored by what we call the hemoglobin or the coloring matter of the red blood corpuscles. In other words, the color of the darker varieties of tartar is derived from the coloring matter of the blood which undergoes a variety of changes in color when it is subjected to the preocesses that lead to its decomposition.

It is a familiar fact that a black eye, or any black-and-blue pigmentation of the skin surface due to a bruise is at first red, then grows a little darker because the coloring matter from the blood has weeped out into the surrounding tissues; then it undergoes chemical decomposition, with a variety of color changes, until it becomes very dark. In the same way when blood oozes out from the gum margin and comes in contact with the tartar this coloring matter is absorbed by the tartar, becomes part of its binding material and undergoes color changes which are quite analogous to those observed in a bruise, that is, from a reddish or brown tint through a variety of color changes down through brown and blue to a final grayish or greenish, almost black, appearance.

Tartar may be pigmented from other causes. It may be pigmented through the activities of certain bacteria that are color-producing, or it may be pigmented by the character of the food or other material that is taken into the mouth as in the case of the betel-nut-chewer, or as in the case of tobacco-chewers or smokers.

The solubility of tartar is an important consideration from a practical point of view. We have had to depend thus far almost altogether upon mechanical instrumentation for the removal of these deposits, for the reason that we have had no proper solvent for this material, something that will disintegrate it without endangering the texture of the teeth. The enamel of the teeth is composed of the same mineral ingredients as tartar, namely, calcium phosphate and a little carbonate. Therefore, generally speaking, a solvent of tartar will necessarily also be a solvent of enamel, and it is a very difficult proposition to apply a solvent to the tartar without damaging the teeth.

There are instances, of course, where the importance of the removal of tartar in certain positions may warrant that risk, if the solvent is applied intelligently and quickly neutralized if it tends to affect the teeth detrimentally. But, broadly speaking, the chemical problem is to find something that will dissolve tartar, but will not dissolve the tooth structure. We would be safer if we could find some chemical solvent that would dissolve, not the calcium phosphate, but the binding material that holds the calcium phosphate together, *i. e.*, the mucin; but the calcium phosphate is soluble in acid, while the mucin is not. Mucin is soluble in alkali while calcium phosphate is not soluble in alkali, at least in any such strength as can be borne in the mouth. So we are confronting a very delicate problem. It is like trying to use a germicide strong enough to kill bacteria without killing the individual that is infected by them; to find an agent selective in its action, so that it will damage the germ and not damage the host of the germ.

Certain substances have been used as tartar solvents with a fair degree of success. Lactic acid has the property of dissolving the calcium phosphate and of forming soluble salts of calcium phosphate and may be applied as a tartar solvent. It is not a vicious acid in attacking the tooth structure, and may be applied to remove the last particles of tartar after the bulk has been removed mechanically by instrumentation. Solvents should not be used for the removal of the bulk of tartar deposits; they are indicated only for the removal of the last remnants. It should never be forgotten that all the other pieces of tartar are of minor, even negligible importance as compared with the last piece. A man may walk one hundred miles and take many thousand of steps through storm and weather to reach his home, but if he does not take the last step over the doorway, he is not home yet. He may die before he lifts the latch. He has not reached his destination. All his previous steps count for nothing. It is quite the same with reference to the removal of deposits. It is not all those that have been taken off which count. It is the last one that counts, and when that is removed the work is done. The last fragment of tartar sometimes even the most delicate tactile sense may fail to detect, especially if it is situated down toward the end of the root of a tooth, or in a pocket which has been thoroughly gone over with the instrument, yet one is not sure whether a small particle has not been left. It is in such a place that we may have recourse to the use of a solvent such as lactic acid.

Dr. Joseph Head, of Philadelphia, has promulgated a preparation known as "Tartasol," which is said to be a solution of a certain percentage of acid ammonium fluorid. I have had no personal experience with it, but it is said by its inventor to have the desirable selective property which we have referred to, that it will dissolve tartar, but not tooth structure. If this is so, it should be a very useful agent, excepting in certain cases in which it is reported to have had a decidedly irritant effect upon the soft tissues about the teeth; therefore it should be used with discretion.

A word should also be said about the solubility of the bacterial plaque. As this plaque is produced mainly by precipitation of mucin by acids, it is perfectly soluble in alkalies. The alkali that is a natural solvent of mucin precipitated by acid is calcium hydroxide, the solution of which we ordinarily speak of as lime water. A solution of three parts of lime water with one part of hydrogen dioxid has greater efficiency than lime water as a means of removing the bacterial plaque. The lime water renders the mucin soluble so that it can be washed off the teeth, and the hydrogen dioxid disintegrates the plaque, so that this solution has a doubly favorable action. It should be used habitually as a dentifrice by all patients who are known to be constitutionally susceptible to caries.

The sources of the discoloration of tartar to which I referred are also the sources of the discolorations that we find on teeth, especially in children, which are spoken of as green stain or brown stain. There are two sources. The coloring matter of the blood is the proteid substance called hemoglobin. When in solution in the course of a short time, this color undergoes a change, becoming bluish or more purplish in color as the hemoglobin decomposes. In the course of further decomposition it assumes a greenish tint. This color change can be effected much more quickly by adding hydrogen sulphide to the blood. Hydrogen sulphide is produced by decomposition of albuminous matter, as in the decomposition of an egg, which then gives off that peculiar odor of hydrogen sulphide, which is due to the decomposition of the sulphur elements in the albumin, and it is the hydrogen sulphide arising from decomposition of the albuminous or proteid elements of the blood acting on the hemoglobin that changes its color to a dirty greenish tint.

In cases of irritation of the gum margin, a little of the coloring matter of the blood weeps out, putrefactive changes go on through the agency of mouth bacteria, and the albuminous portions of the saliva and the blood putrefies. Hydrogen sulphide is given off, the sulphur compounds unite with the coloring matter of the blood and produce that green or greenish-brown stain observed on children's teeth and the teeth of those having irritated and bleeding gums in uncleanly mouths. The chemical make-up of the pigment of that stain is the decomposition product called sulphomethemoglobin. The children's teeth upon which it is observed are not properly kept clean. They have a history of lack of practical acquaintance with the toothbrush, and the ordinary technic of the dental toilet.

Another of these green stains is in all probability due to pigmentations of the normal covering of the enamel of the young tooth, which we speak of as Nasmyth's membrane, by certain color-producing or chromogenic bacteria bringing about that characteristic color.

By treating the young tooth with very dilute acids we can isolate Nasmyth's membrane and examine it under the microscope, when we find it permeated with what looks like the result of bacterial activity.

Both these types of green stain upon the tooth surface are readily removable by the application of iodin, and the subsequent use of polishing powders or pumice applied on an orange-wood stick. Iodin is not only an antiseptic, but also a bleaching agent. That sounds very peculiar, because it stains, but we can stain the surface structure of a tooth to a deep tint with iodin and simply let it alone, and when the patient returns the next day that tooth will be much lighter in color, due to the bleaching action of the iodin. We need never be afraid of permanently tinting a tooth with iodin, unless we apply it with a steel instrument, when iodid of iron is formed and a permanent stain will be produced. Iodin itself may be used with perfect freedom upon tooth surfaces free from metallic fillings for the reason that it is ultimately a bleaching agent.

CHAPTER VII.

DENTAL CARIES.

By EDWARD C. KIRK, Sc.D., D.D.S., LL.D.

Dental caries, or as it is commonly designated, tooth decay, is a disease which is practically universal in its distribution. It affects all civilized peoples, some uncivilized tribes and, under certain conditions, even some of the lower animals. No disorder that afflicts the human race is more common, as it has been shown by abundant statistics that from 85 to 95 per cent. of civilized human beings are more or less the victims of dental caries or have suffered from its ravages at some period of their lives. Dental caries is essentially a disease of childhood and adolescence, the developing individual appears to be peculiarly susceptible to its invasion, whereas when adult life is reached the tendency to tooth decay is noticeably lessened so that in the majority of cases when the individual has reached full maturity the progress of tooth decay appears to be markedly arrested. So manifest are these differences in the activity of dental caries as related to the age and development of the individual that the conditions of susceptibility and immunity to the disorder are accepted as characteristic of its activity. As further evidence of the same characteristic a small proportion of individuals are found to be quite free from any evidences of tooth decay, never having suffered from its invasion at any time or in any degree, these are regarded as being naturally immune.

The period of childhood and adolescence being the period of greatest susceptibility to dental caries makes its relationship to the health of children of school age one of vital importance, not only from the hygienic point of view but upon educational and economic grounds as well.

Comparatively recent studies of the question furnish abundant evidence of the fact that the prevalence of dental caries among children of school age is the fruitful primary cause of mental backwardness, interrupted brain development, nervous disorders, errors of vision and of hearing, bodily malnutrition and a host of evils which not only retard or interfere with the educational process but impair the physical and mental efficiency of these developing citizens of the future generation to a serious degree. Hence the importance of not only a proper understanding of the nature of this important disorder but a clear appreciation of its gravity as a menace to human health and efficiency.

For purposes of anatomical description a tooth is viewed as having a crown (corona) which is all that part of the tooth exposed beyond the gum, and a root (radix) or radicular portion which is all that part of the tooth embedded in the bony socket or alveolus beneath the gum. The portion at the gum line between the crown and the root is designated as the neck (cervix) of the tooth.

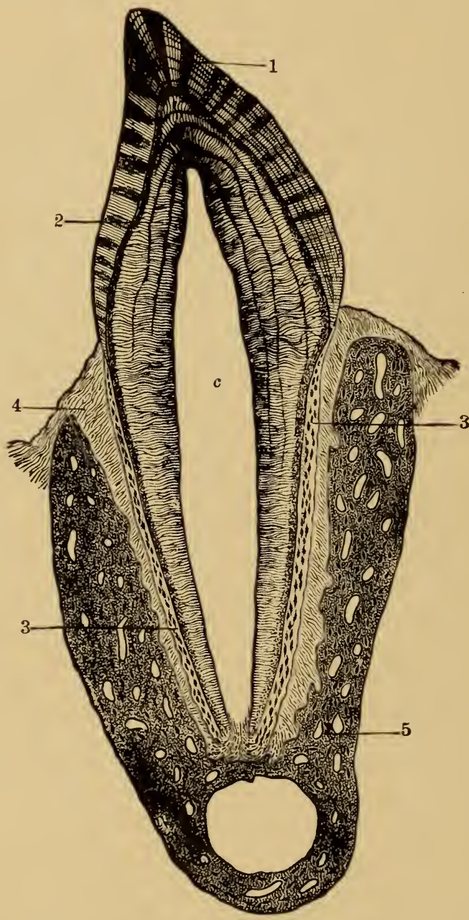

FIG. 58.—Vertical section of a tooth *in situ* (15 diameters). *c* is placed in the pulp cavity, opposite the cervix, or neck of the tooth; the part above is the crown, that below is the root (fang); *1*, enamel with radial and concentric markings; *2*, dentin with tubules and incremental lines; *3*, cementum or crusta petrosa, with bone corpuscles; *4*, pericemental membrane: *5*, bone of mandible,

Dental caries is a destructive process affecting the hard dental tissues; these are three in number: (1) the enamel which is the hard outer protective covering of the underlying dentin of the tooth crown and (2) the cementum or crusta petrosa covering the dentin of the root; and (3) the dentin which forms the principal body of the tooth. Within the body of the dentin in the central cavity of the tooth is located the tooth pulp, a soft, highly sensitive and vascular organ, commonly but incorrectly called the "nerve." From a group of specialized cells upon the surface of the dental pulp there radiate through the dentin innumerable fibers of living matter, richly endowed with sensation, which with their lateral processes ramify throughout the dentin structure. These are termed the dentinal fibers or fibrillæ, and it is through their agency that we perceive the painful impressions arising from irritation of the dentin by cutting, by heat, cold, sweets, etc.

Dental caries always has its inception upon the external or exposed surface of a tooth; it never arises from within the tooth. For a long period it was held by many students of the subject that tooth decay

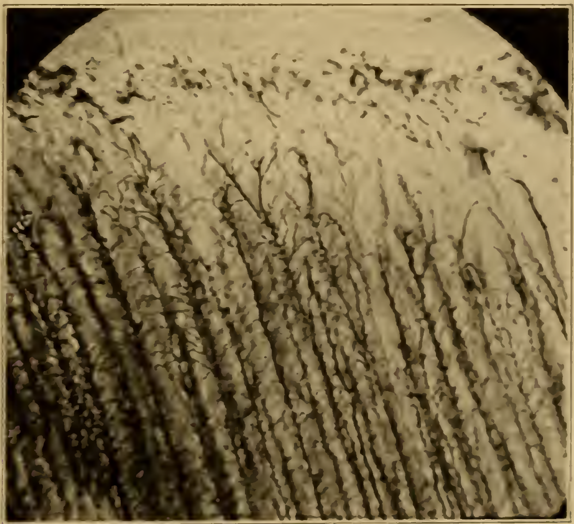

Fig. 59.—Longitudinal section of dentin showing distribution of dentinal fibers and stratum granulosum. (Miller.)

was an inflammatory process similar in certain respects to necrosis of bone and those who accepted that view also held that caries originated within the tooth structure and gradually progressed outwardly toward the free enamel surface. This theory was maintained by some until quite recent times, but its fallaciousness was finally completely demonstrated by the researches of the late Prof. Dr. W. D. Miller, published about 1880, which finally gave to the world the true explanation of the process of tooth decay.

Briefly stated, Miller, as the result of a long and exhaustive experimental study of the subject, found that the destruction of the hard structures of the tooth by dental caries was accomplished through the agency of a certain class of microörganisms which had the characteristic function of fermenting certain of the sugars and converting these sugars into lactic acid, which acid in its turn attacked the solid structure wherever it came into contact with it, dissolving out its mineral matter which caused the structure to disintegrate, forming a cavity which gradually enlarged until it eventually included the entire crown; indeed, if unchecked, the whole tooth may in this manner become disintegrated and lost.

A tooth, however, is not wholly composed of mineral matter soluble in lactic acid. If we immerse a tooth for a sufficient length of time in an acid, for example, dilute nitric or hydrochloric acid, it will be found to have lost all of its enamel covering and the remaining dentin and cement structures while still possessing the general conformation of the original tooth will be found to have lost their hardness to such a degree that the structure may then be easily cut with a knife into chips or slices like a piece of cartilage which the structure now closely resembles. We say of a tooth so treated that it has been decalcified, that is to say, the calcium or lime salts which gave to the tooth structure its characteristic hardness have been removed or dissolved out by the acid and what remains is an organic substance or animal tissue called the organic matrix or basis substance of the dentin and cementum.

The relative proportions of calcium salts or mineral matter and organic matrix or tooth cartilage in the dentin and enamel structures are shown in the following analysis:

DENTIN (Von Bibra).

Tooth cartilage	27.61	Organic matter
Fat	0.40	
Calcium phosphate and fluoride	66.72	Inorganic matter
Calcium carbonate	3.36	
Magnesium phosphate	1.18	
Other salts	0.83	

ENAMEL (Von Bibra).

Cartilage	3.39	Organic matter
Fat	0.20	
Calcium phosphate and fluoride	89.82	Inorganic matter
Calcium carbonate	4.37	
Magnesium phosphate	1.34	
Other salts	0.20	

ENAMEL (Kuehn).

CaO	53.75
MgO	0.84
P_2O_5	37.21
Fl.	0.29
Organic matter and H_2O	8.48

DENTIN (Kuehn).

CaO	53.42
MgO	2.41
P_2O_5	39.46
Fl.	0.25
Organic matter and H_2O	32.10

Miller showed that the first phase of the carious process was a dissolving out of the mineral substances or decalcification of the tooth structure by lactic acid produced by the ferment action of certain microörganisms on sugars. He further showed that when decalcification had taken place, infection of the exposed organic matrix of the tooth structure by a different type or class of microörganisms occurred, these latter known as proteolytic bacteria, had the power to liquefy and bring about putrefaction of the organic matrix and to destroy it in the same manner that a dead animal body is destroyed and disintegrated by putrefactive changes. These two phases of the carious process are essentially the same in principle, dependent upon the vital activities of microörganisms of two distinct groups, each having the power to decompose certain compounds which enter into the formation of tooth structure and to produce by their action certain characteristic physical phenomena and certain end or decomposition products equally characteristic. Thus in a cavity of decay the presence of acid may be easily demonstrated by bringing into contact with the decaying mass a strip of blue litmus paper which will at once turn red where the decaying mass touches it. The characteristic odor of putrefaction is readily recognizable, indeed, offensively so, in the breath of those suffering actively from tooth decay. This odor of putrefaction arises in large part from the decomposition of the organic matter of the dentin matrix through the agency of the proteolytic bacteria.

The human mouth is not only the portal of entry for many disease-producing microörganisms, but because many of these microscopic vegetable organisms thrive, flourish and rapidly reproduce themselves under the conditions of moisture, temperature and food supply that they find in the mouth cavity many species continue to inhabit the mouth and those which are possessed of disease-producing characteristics become the agency of infection by which a variety of bodily diseases are produced. An unclean mouth is therefore a constant menace to bodily health as well as the ordinary source of tooth decay. Fig. 60 shows a mixed infection of various bacteria from a tooth surface.

But though a great variety and an almost infinite number of microorganisms are constant inhabitants of the mouth, and though the lactic-acid-producing bacteria which cause tooth decay are found in nearly all human mouths, it is well known that many teeth do not decay, and even where the decay process is active not all surfaces of the teeth are equally vulnerable to the process of decay.

It has long been noticed that certain locations or areas upon the tooth surfaces are more liable to be the seat of decay than are certain other surface areas. In general, it may be said that those surfaces of the teeth that are subjected to the cleansing action of friction by the tongue, the lining mucous membrane of the lips and cheek surfaces or teeth surfaces which are kept free of bacterial invasion by the friction of rough or fibrous food materials, are less liable to decay; whereas, those surfaces of the teeth not subject to the self-cleansing action of the foregoing causes are most likely to be the seat of decay, as shown in Fig. 61.

Locations where food particles infected by mouth bacteria can find an undisturbed lodgement, such as the natural pits and depressions in the masticating surfaces of the molars and premolars, the sulci between the cusps, and especially the approximating surfaces of the teeth which by their mutual relations of contact afford protected areas for the

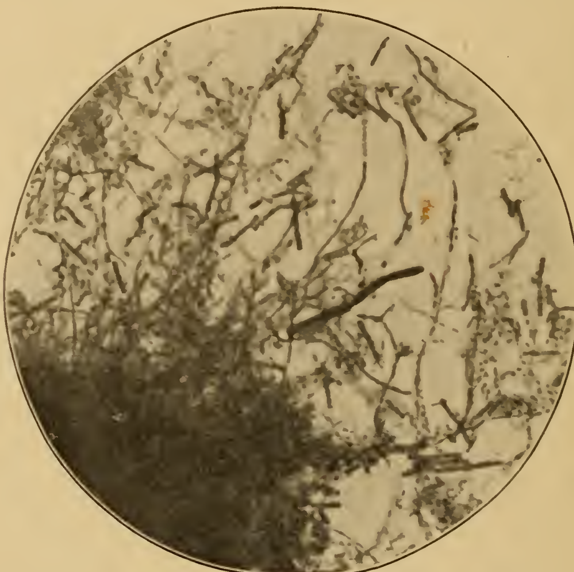

Fig. 60.—Mixed infection from tooth surface. (Williams.)

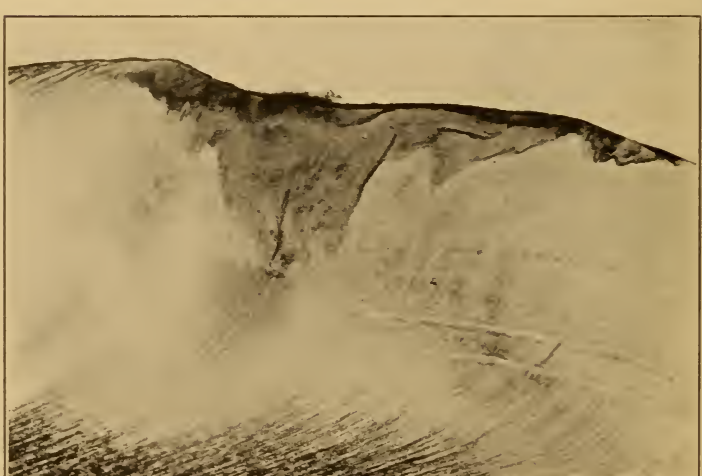

Fig. 61.—Caries localized above the "contact point" on the approximating surfaces of contiguous molar teeth. (Williams.)

lodgement of food particles and its undisturbed decomposition by lactic-acid-producing bacteria are areas which in a susceptible individual are the selected locations of the carious process (Figs. 62 and 63).

The determination of the location of tooth decay is in large degree a result of the form of the individual tooth and of the relations of the teeth to each other in the dental arches.

FIG. 62.—Beginning caries in sulci and enamel defects of morsal surface of a molar, also showing transparent zone of Tomes. (Miller.)

FIG. 63.—Beginning caries on approximal surface. (Miller.)

The structure of the tooth itself, that is to say, whether it be hard and dense or whether it be relatively soft and imperfectly calcified, does not in the slightest degree influence the liability of teeth to decay or otherwise. Any tooth will decay in a mouth where the conditions causing decay are active and no tooth will decay whatever its structure may be in a mouth where the conditions causing decay are not active. Or, as stated by the late Prof. G. V. Black, "decay of the teeth is a factor of the environment of the teeth. It is not due to the structure of the teeth insofar as their structure is characterized by density, hardness, softness, etc. These factors may influence the rate of decay but they do not determine the liability to decay."

When starchy food particles, sugars or any form of fermentable carbohydrate food material is lodged in contact with a protected area of tooth surface it becomes subject to the action of lactic-acid-producing microörganisms and undergoes fermentation resulting in its decomposition with the production of lactic acid. A familiar example of this process is the souring of milk when left exposed for a time to the air at a warm room temperature. Milk contains a considerable quantity of a characteristic sugar called sugar of milk and chemically designated lactose, having the formula $C_6H_{12}O_6$. Bacteria from the air fall into the milk and set up a fermentation of the milk sugar decomposing it or splitting it into lactic acid which when it accumulates sufficiently, gives the milk an acid reaction and a sour taste. The acid thus formed breaks up the combination of the casein with the base with which it was in chemical union and precipitates the casein as a curd so that the milk becomes thickened and when separated from its watery whey, this curd is the material from which cheese is made.

The casein or cheesy portion of the milk will also undergo putrefactive changes through the agency of proteolytic and other forms of bacteria which have the property of decomposing this type of organic matter so that the process of fermentation and subsequent putrefaction of milk is, in principle at least, quite analogous to the process of tooth decay.

The conversion of sugar into lactic acid by the fermentative agency of bacteria is represented by a chemical formula as follows:

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} + \text{the enzyme of B. acidi lactici} = \underset{\text{Lactic acid.}}{2C_3H_6O_3}$$

that is to say, a molecule of the monosaccharid glucose is, under the action of the enzyme of the B. acidi lactici, split up into two molecules of lactic acid. Starches, cane sugar and the more complex carbohydrates must first undergo changes in the mouth into the simpler forms like glucose before they can be split into lactic acid and these preliminary changes are brought about by other enzymes, and particularly by ptyalin, the characteristic ferment of the saliva which possesses marked amylolytic properties or the power to convert starches into sugars that may be subsequently broken into lactic acid by the agency of the proper bacterial enzyme.

These chemical alterations as the result of the action of digestive ferments and bacterial enzymes upon the débris of food substances are constantly going on in mouths which are not kept clean and free from food remnants either by habitual use of the usual tooth-cleansing devices of brush and dentrifices, unless we may exclude those exceptional cases which are naturally self-cleansing and therefore immune. It is this constant fermentative activity that initiates dental caries wherever on a localized area of tooth structure it is permitted to continue undisturbed.

It should be borne in mind that dental caries is a distinctly localized process in its inception. The disease may appear in one or many places in the same mouth, at the same time, but it is localized in the sense that it does not attack all surfaces of the teeth simultaneously, nor with equal impartiality. Many who in the beginning of their study of the pathology of dental caries have clearly grasped the fact that lactic acid is the agent which initiates the disorder by dissolving out the lime salts of a localized area of tooth structure, and that the first stage of cavity formation is thus explained, not infrequently jump to the erroneous conclusion that lactic acid alone is the cause of tooth decay and cavity formation.

As a matter of fact, a generally acid saliva, even if the acidity be due to lactic acid, will not give rise to tooth decay. An acid saliva is destructive of tooth structure by bringing about a general decalcification of the teeth which is manifested more intensely in certain locations than in others, but this type of destruction of tooth structure is not dental caries but what is called chemical erosion of the teeth, a disorder not necessarily dependent upon bacterial activity, as it may be produced by any free acid formed in the mouth, exuded into the mouth, or taken into the mouth.

Dental caries is a characteristic disease with a well-marked and definite group of symptoms and within certain limits it has a known causation, which is the localized destruction of the hard tissues of the tooth by the solvent action of lactic acid generated at the point of decay by the agency of bacteria acting upon carbohydrate foodstuff.

While localization of the decay process is to a large degree determined by the forms of the teeth and their relations to each other, as already explained, there is another and somewhat complicated method by which fixation of lactic-acid-producing bacteria to a tooth surface is brought about, a method which because of its importance in relation to oral hygiene as well as to the causation of decay should be clearly understood and that is the localization of decay-producing bacteria upon the tooth surfaces by the precipitation of mucic acid from the mucin of the saliva by the lactic acid set free by the activity of the bacteria themselves.

The precipitation of the mucic acid upon tooth surfaces is discussed in detail in the chapter on Deposits Upon the Teeth, as it is a result of bacterial activity responsible to a considerable degree for the formation of those adhesive deposits upon the teeth to which the general designation of tartar is applied; it is important to recapitulate its main features here insofar as they are concerned in localizing the process of dental caries.

In mouths where caries is in active progress the saliva is ordinarily rich in mucin which when present in appreciable quantities, is recognizable by the glairy or ropy, adhesive character of the fluid. The saliva has the property of viscosity; it has a certain cohesiveness and may be drawn out into threads of greater or less length according to the quantity of mucin that it holds in solution. Such saliva is nearly neutral or faintly alkaline in reaction. If to a small quantity of such a saliva gathered in a test-tube a drop of lactic acid, or, indeed, any acid is added, there will be formed at the point of contact an opalescent precipitate which is the mucic acid set free from the alkaline base with which it was previously in chemical combination in the saliva as mucin.

If the test-tube is allowed to stand undisturbed for some minutes, the precipitate will settle to the bottom of the glass. The precipitated mucic acid is adhesive and insoluble except in an alkaline or saline solution. If now we apply these data to our study of what takes place in the mouth, we shall find that they throw much light upon the mode of localization of the carious process.

Assuming that in a susceptible mouth the saliva is rich in mucin held in solution by the alkaline salts of the saliva and that the mouth contains carbohydrate food material in the form of soluble sugars, the result of the amylolytic action of the salivary ferment ptyalin upon starchy food débris, then, in such a mouth infected by lactic-acid-producing bacteria, one or more of these organisms falling upon a tooth and temporarily lodged in some irregularity of the enamel surface, immediately sets up a fermentative action in the soluble sugar in its salivary environment setting free lactic acid in its immediate vicinity. The liberated acid at once decomposes the dissolved mucin of the saliva throwing down the adhesive mucic acid in contact with the body of the microörganism, cementing it, as it were, to its position upon the enamel surface. Multiplication of the bacteria proceeds rapidly and the process of acid production and mucic acid precipitation proceeds in harmony with the bacterial multiplication. The mass of bacteria thus organized and cemented to the tooth surface constitutes what is known as the bacterial plaque, the essential factor in the localization of tooth decay and the most important characteristic in the causation of the disease. (See Fig. 64.)

The bacterial plaque presents a variety of physical appearances under the microscope. It may exist as a small glistening semitransparent mass occupying only a small spot of the enamel surface or it may present the appearance of a film extending over a considerable area, in fact, over all surfaces of the tooth not subject to friction by food or the tongue and buccal mucous surfaces. The microörganisms found in the plaque are never a pure culture of lactic-acid producers but while these are presumably always present, the organisms are usually those constituting the mixed infection usually found in the unclean mouth (Fig. 60).

It has been shown that tooth decay is brought about in the first place by the decalcifying action of lactic acid produced by the ferment action of bacteria upon carbohydrate food débris. This is, however, a general statement of fact that requires somewhat closer analysis in order that the exact nature of the process may be more clearly understood. All carbohydrate material is not directly fermentable into lactic acid, thus cane sugar and starches, two important nutritive substances, must undergo certain chemical changes in the mouth by which they are converted into simple forms of sugar, the mono-

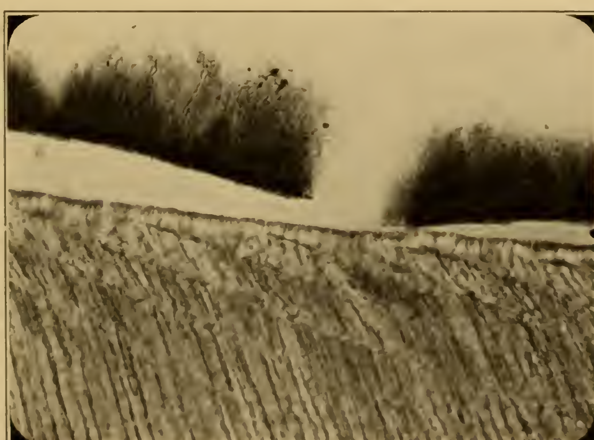

Fig. 64.—Bacterial plaque, detached from enamel surface of the tooth in making the preparation. (Williams.)

saccharids having the general formula $C_6H_{12}O_6$, before the bacteria of tooth decay can convert them into lactic acid, this preliminary change called hydration or hydrolysis, is brought about in the case of starches by the ferment ptyalin, an enzyme produced by the salivary glands and which is therefore a normal constituent of the saliva. Its function is to prepare the starches and possibly some of the more complex sugars for later assimilation by the cells of the body in the process of nutrition.

The physiological chemist Claude Bernard showed by experiment that cane sugar as such is not assimilated by the human organism when injected into the veins, but when taken into the mouth is later acted upon by a special amylolytic enzyme called invertase in the intestinal canal and is thereby converted into a monosaccharid assimilable sugar suitable for the nutrient purposes of the organism.

The typical conversion of starch and of cane sugar respectively into lactic acid may be shown chemically as follows:

$$\underset{\text{Cane sugar.}}{C_{12}H_{22}O_{11}} \quad + \quad H_2O$$

becomes hydrolized through the action of invertase to

$$C_{12}H_{24}O_{12} \quad = \quad \underset{\text{Glucose.}}{2C_6H_{12}O_6}$$

which through the enzyme action of B. acidi lactici is split into

$\underset{\text{Lactic acid.}}{4C_3H_6O_3}$ and starch $C_{12}H_{20}O_{10} + 2H_2O$ becomes hydrolized through the action of diastase, or ptyalin, to

$$C_{12}H_{24}O_{12} \quad = \quad \underset{\text{Glucose.}}{2C_6H_{12}O_6}$$

which through the enzyme action of B. acidi lactici is likewise split into

$$\underset{\text{Lactic acid.}}{4C_3H_6O_3}$$

From the foregoing it will be seen that the mother substance from which mouth bacteria produce lactic acid is a simple form of sugar belonging to the monosaccharid group of sugars called the hexoses from their chemical constitution, all having the formula $C_6H_{12}O_6$, a compound which readily splits into two molecules of lactic acid having the formula $2C_3H_6O_3$. The sugars being soluble substances readily diffuse into or are capable of absorption by the bacterial plaque so that the bacteria thus fixed and localized upon a protected tooth surface are nourished by a food supply of soluble sugar directly convertible into lactic acid which being produced continually in these localized areas of bacterial fixation exerts its solvent and decalcifying action upon the enamel without interference.

The manner in which enamel disintegrates under the solvent action of lactic acid is both interesting and important. The enamel covering of a tooth crown is made up of innumerable prismatic rods or prisms irregularly hexagonal in section and densely calcified. These enamel prisms stand endwise to the dentin and pursue a radiating and sometimes wavy course to the periphery or free enamel surface. The prisms are bound together by a material of much the same chemical nature as that constituting the prisms themselves, but it differs therefrom in the physical sense that it is more readily soluble in acids. If we take a thinly ground section of enamel and place it on a slide and while examining it under the microscope allow a drop or two of dilute acid to act upon the free edge of the specimen, we will see that the acid dissolves out the interprismatic cementing substance much more rapidly than it affects the structure of the prisms themselves; hence the acid, because of this greater solubility of the interprismatic cementing substance, tends to penetrate between the prisms separating them from each other and causing them to fall apart as shown in Fig. 65.

It is precisely this effect that we see in the opaque chalky white spots that make their appearance upon susceptible tooth areas and which the intelligent operator recognizes as the beginning of dental decay. The opacity and chalky appearance of these spots is due to the fact that the interprismatic cementing substance that formerly gave the appearance of homogeneity to the enamel structure has been dissolved out leaving air or fluid in its place having a different refractive index than the enamel (Fig. 66). As the process proceeds the area enlarges and the enamel rods having lost the means of mutual support, fall apart and are lost, leaving an open cavity in their former location.

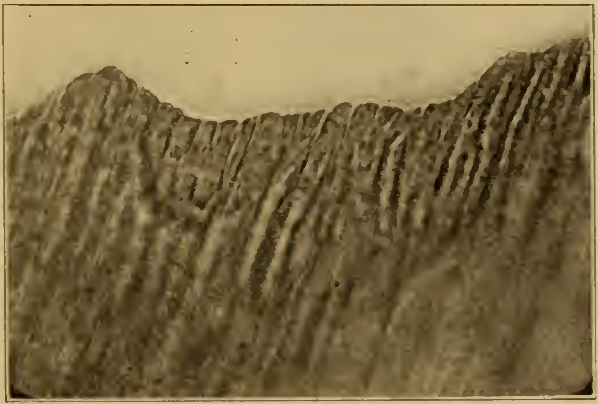

Fig. 65.—Section of enamel subjected to the action of dilute acid showing solvent effect on the interprismatic cementing substance and penetration of the acid between the enamel rods. (Williams.)

The irritative effect of the gradual penetration of acid through the enamel in the process of tooth decay is manifest at a very early stage. Even before an actual cavity has been formed or the acid penetration has reached the junction of the enamel with the dentin, the latter tissue will have manifested its reaction to the irritation by recording certain characteristic changes in its structure. In a section of a tooth attacked by slowly advancing caries there will be noticed in the structure of the dentin lying subjacent to the line of invasion a cone-shaped area between the dentino-enamel border and the pulp cavity with the apex of the cone toward the pulp and the base toward the disinstegrating enamel. This cone-shaped area of dentin is more transparent than the surrounding dentin structure and from its peculiar transparency has been called the transparent zone of Tomes, from Sir John Tomes, who first described it. Various theories as to the cause of this alteration in the character of the dentin structure have been advanced, and such authorities as Tomes, Magitot, Miller and Walkhoff regard it as being an overcalcification of the dentin structure as a result of the irritation of the living matter of the dentin. Certain it is that it is the expression of a vital reaction upon the part of the dentin, for it does not occur in dead (*i. e.*, pulpless) teeth and it always does occur from long-continued slight irritation to the dentin from whatever cause. Its main importance in connection with the study of dental caries is that it records indisputably the fact that dental caries in its progress sets up irritation which is felt and recorded by the vital elements of the tooth, even in the earliest stages of the disease and before the integrity of the enamel surface has as yet been seriously disturbed (see Fig. 62, *a*).

CARIES OF DENTIN.

When the enamel has been penetrated and a cavity has thus been formed, invasion of the dentin rapidly follows. Caries of the dentin differs from caries of enamel in two important particulars arising out of the differences in structure and composition of the dentin as compared with that of the enamel.

The dentin contains a relatively larger amount of organic matter than the enamel; the earthy salts entering into the composition of the dentin are deposited in a cartilaginous substance having the general form of the tooth and known as the organic matrix or basis substance of the dentin. The organic matrix which in the formed tooth is fully calcified is everywhere permeated by fibrils of sensitive living matter encased in tubules which radiate from the surface of the pulp through the dentin structure. It is these fibrils of living matter that endow the dentin with sensation and which give rise to pain when the dentin is cut as in the preparation of a cavity of decay preparatory to the filling operation or when sweets, acids or other irritating substances are brought into contact with the walls of a carious cavity.

The distribution of living matter in the dentin may be seen from Fig. 59, which is reproduced from a photograph of a section of the dentin cut in the plane of the long axis of the tubules in which the fibrillæ run.

As soon as loss of enamel exposes the ends of the dentinal fibrillæ invasion of the tubules by the bacteria of decay promptly takes place and the tendency of the carious process is to follow the direction of the tubules toward the dental pulp.

Within the dentinal tubule the bacteria of decay elaborate their characteristic lactic acid which dissolves the sides of the tubule enlarging its diameter, the increased space being promptly packed with organisms reproduced from the parent pioneers of the invasion the dissolution of the tubular walls continuing until the area of decalcification involves adjacent tubules which have been undergoing a similar process of enlargement until coalescence of a number of tubes takes place (Figs. 67 and 68). Coincidently, as decalcification proceeds and exposure of the organic matrix occurs, that structure is attacked by a

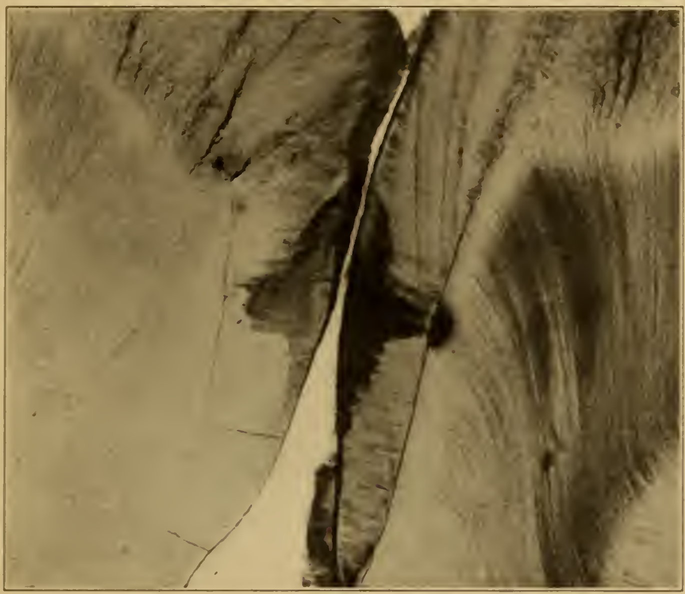

Fig. 66.—Section of tooth showing localized solution of interprismatic cement substance with enamel rods standing, constituting the "opaque spot" of beginning decay. (Miller.)

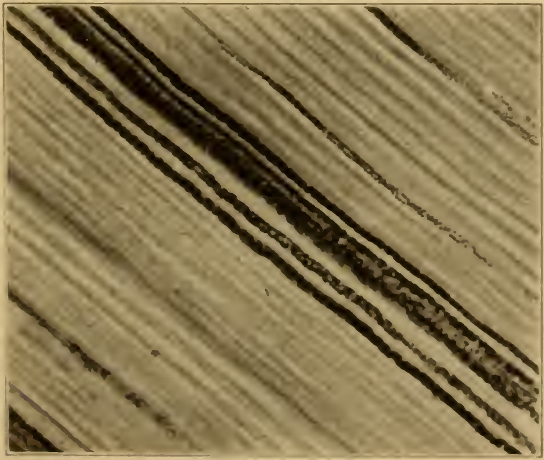

Fig. 67.—Longitudinal section of carious dentin showing enlarged tubules packed with bacteria. (Miller.)

group of bacteria known as proteolytic organisms which have the property of elaborating an enzyme that brings about liquefaction of the cartilaginous proteid material constituting the organic matrix.

Decomposition and putrefaction of the decalcified basis substance of the dentin thus takes place with the formation of so-called liquefaction

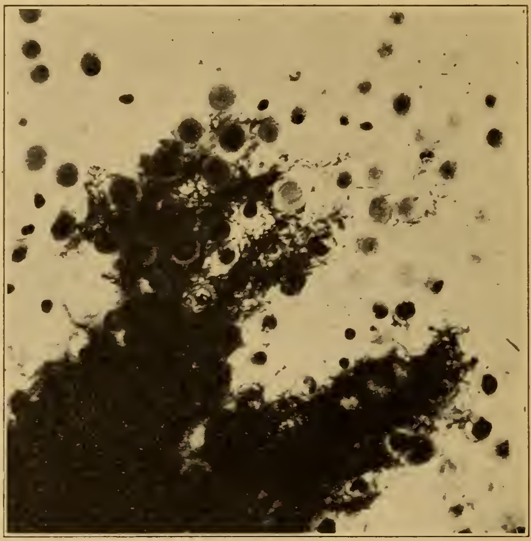

Fig. 68.—Cross-section of carious dentin showing enlarged tubules. (Miller.)

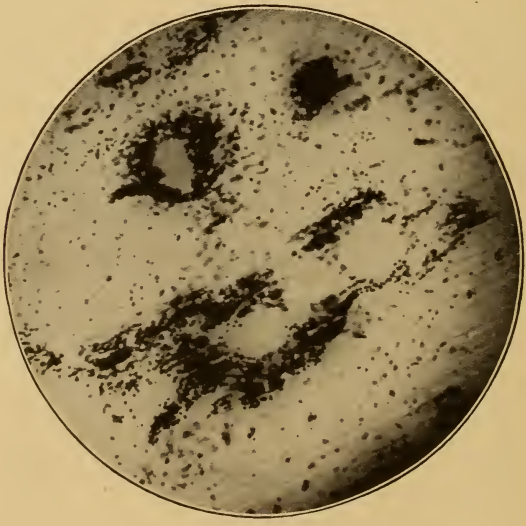

Fig. 69.—Liquefaction foci in carious dentin. (Miller.)

foci in the dentin which liquefaction foci by their extension and coalescence ultimately produce what is commonly known as a cavity of tooth decay, the process continuing until the pulp is reached or, if the process is not arrested, until the tooth is destroyed (Fig. 69).

It has already been noted that invasion of the dentin by the bacteria of caries is by way of the dentinal tubules which these organisms, generally speaking, follow toward the pulp and various considerations seem to indicate that this mode of invasion of the dentin is largely determined by the fact that the source of food upon which the organisms feed is found in the substance of the dentinal fibril or the juices of the fibril itself.

It has been clearly demonstrated by the researches of Miller, already referred to and confirmed by other able and trustworthy investigators, that dental caries can be, and is, due to decomposition of carbohydrate food particles in unclean mouths, from which we have drawn the conclusion that tooth decay is a filth disease, that if proper care as to oral hygiene is instituted and maintained that dental caries may be eradicated; in short, we have come to regard it as an accepted fact that "clean teeth will not decay." This conclusion is probably too hastily drawn and without full consideration of all the factors involved.

Experience shows that teeth decay more rapidly in early than in adult life, that the teeth of some individuals decay more rapidly than others, that the teeth of some never decay, that many who give scrupulous attention to their teeth are extremely susceptible to decay of the teeth, while others whose mouths never receive any attention appear to be immune.

The problems of susceptibility and immunity to dental caries are as yet unsolved; there are, however, many indications that give color to the hypothesis that there are certain nutritional factors that have much to do with the susceptibility to dental caries or with immunity therefrom. Those who live upon an excessive carbohydrate diet are, as a rule, found to be more prone to carious invasion than those whose diet is largely of a proteid character. Probably under an excessive carbohydrate diet the percentage of sugar in the blood, normally about 0.001, is increased and if the salivary fluids and the juices of the dentinal fibrils derived from the blood reflect this increase in carbohydrate above the physiological normal would readily invite the invasion of decay-producing bacteria. In 1881 Milles and Underwood expressed the opinion that the bacteria feed upon the juices of the dentinal fibrillæ in dental caries as follows: "The organic fibrils upon which the organisms feed and in which they multiply are the scene of the manufacture of their characteristic acids, which in turn decalcify the matrix and discolor the whole mass."[1]

If, then, susceptibility to tooth decay is in considerable degree dependent upon a constitutional predisposition, oral hygiene alone and unaided cannot wholly prevent it, although it can undoubtedly greatly

[1] Trans. Seventh International Congress of Medicine, London, 1881.

diminish its ravages. It is highly probable from our present knowledge of the subject that complete control of this universal disorder can never be attained by local measures alone. The fundamentally important question of dietetics, of food habit, must be studied for what light it can throw on the solution of the problem, for even now the evidence is almost overwhelming that the inordinate and habitual use of sweets by civilized children is a custom pernicious alike to the integrity of their dentures and to their general health.

Until the deeper underlying factors of the causation of dental caries are discovered we must rely upon the means at our command in the principles and art of oral hygiene to protect humanity as best we may from the scourge of dental caries and its consequent damage to health and life.

CHAPTER VIII.

THE TEETH AS A MASTICATING MACHINE.

By CHARLES R. TURNER, M.D., D.D.S.

An analysis of the reasons for preserving the teeth gives first importance to their preservation that they may perform their functions as a part of the human organism, and play their part in that sum total of activities which go to make up the physical life of the human animal. As so much attention is now being given to the matter of tooth conservation it is proper to be informed as to the important part taken by the teeth in one of the most essential of the distinctive animal functions, indeed, one which is necessary to the preservation of life itself. Furthermore, it is one of the dictums of physiology that any part of the body which ceases to perform its functions atrophies, or the character of its tissues degenerates, and in course of time is incapable of performing its function; and so the duties of the teeth have a twofold interest for us.

In order then to present the case for the preservation of the teeth, as it were, something must be said about their functions in the human body, and in that connection as a machine, or as a part of a machine, concerned in the preparation of the food for subsequent stages in the digestive process.

To appreciate fully the part taken by the teeth in the activities of the human organism, it might be interesting, and it will certainly give a good background for the study of the human dental mechanism, to take some account of the way the teeth have developed to perform their present functions.

The basal functions of animal as distinguished from plant life, and as fundamental to existence itself, are:

1. Alimentation.
2. Respiration and circulation.
3. Locomotion.
4. Reproduction.

Evolution of Tooth Forms.—In the simplest form of animal life, as for example in a unicellular body, *the ameba*, we have the process of alimentation, or the securing of nutrition, an extremely simple one. The animal is afloat in the water and extracts its nutriment therefrom, the nutritive elements are absorbed through the cell wall and nutrition is effected through a simple process of osmosis.

No one fact so impresses the student of zoölogy as the relationship between the form and structure of the various parts of an animal organism and the functions they are called upon to perform. It is very interesting to note the adaptive modification of the structures to changes in these bodily functions, and to observe how they have been modified during the various stages in the development from the lowest organisms up to the highest forms.

As the scale of animal life is ascended and a multiplication of function occurs differentiations of tissue appearing here and there are found, which occur as a result of a certain function falling upon that tissue. Certain cells are given over to the function of reproduction; certain other cells or collections of cells are specialized for locomotion, etc.

In some of the lower forms of animals, before the vertebrates, there is a simple tube like a channel devoted to alimentation; the food goes in one end and the excreta are ejected at the other. There is no special collection of cells at the beginning of this tube to prepare the food. In the *cœlenterata*, for example, the alimentary canal is not separate from the general body cavity, but in the *annuloida* and *annulosa* it is a distinct tube.

A little higher in the scale, as in some of the insects, the crabs and the crustaceans, there are at the beginning of this alimentary tract cells which are concerned to some extent with the preparation of the food for its passage through the canal. There is no real masticating apparatus, however, even in many of the lowest of the vertebrate animals, but the first thing that at all appears like it occurs in some of the lower fishes, in the *hag-fishes* and in the *lamprey eels*. The latter have a suctorial mouth which they attach to some object, either the side of a larger fish or a stone covered with moss, and obtain their nutrition from it by a process of suction. Inside of this mouth are layers of cells which are rather horn-like in character. They are for the purpose of imbedding themselves in the substance to which the mouth is applied and of affording a firm hold so that the animal may draw its sustenance. This is perhaps the very simplest type of differentiation of tissue for this purpose.

In the vertebrate animals the cells constituting the tissues at the entrance of the alimentary canal are specialized with a view to assisting in the process of either securing or preparing the animal's food. The apparatus is simple in the less highly developed orders and becomes a more complicated instrument as the scale is ascended. The food convenient to the animal or required by it, and the food-reducing mechanism are in constant correspondence. Out of this necessity has developed teeth. The teeth have developed in accord with and to meet the needs of the food which the animal utilizes. They are corneal or horn-like in some of the lower orders and as we go upward they become calcified. They are simple cones or they are modified under certain conditions to forms which serve better their functions.

Fishes are the lowest vertebrate type that have calcified teeth; they are simply calcified cones arranged around the border of the jaws and serve to hold the food. Some of the teeth are recurved and serve like the barb of a fish-hook to prevent the escape of the prey (Fig. 70).

Of the *amphibians* some have no teeth, as the toad, while others, such as the *frog*, have teeth not unlike those of fish, at least always in the upper jaw for the *bullfrog* has no lower teeth.

Of the *reptiles* many have teeth. The lizards eat butterflies, worms, insect larvæ, etc., while *snakes* live on amphibians and their larvæ and fish, and the *viperine snakes* on small mammals. *Crocodiles* and *turtles* eat fish, small amphibians and insects. The snakes do not chew their prey but swallow it whole. The lower jaw is jointed in the center and articulates with the skull through the quadrate bone, thus allowing the mouth to open very wide, but the teeth serve only for seizing and holding the prey. In the venomous snakes in the upper jaw are found the "poison fangs" which have a channel leading to the poison sac. The *chelonidæ* or *turtles* have a horn-like covering for the border of the jaw.

FIG. 70.—Specialized conical teeth in the higher order of fishes.

The *birds*, of course, have no teeth, the beak being a horny sheathing of the ends of the jaw-bones. In some the edge is serrated. In no other class is found a greater variation in the food-preparing apparatus, or greater adaption to the food supply. The beak serves largely to obtain the food. In the grain-eating birds the gizzard performs mastication. Ducks have soft-edged beaks for sifting the food out of the mud. The skulls of the *hawk*, *heron*, *English sparrow*, *crow*, and *toucan* shown give an idea of this variation. The crow subsists largely on grain, and very often takes grain such as corn out of the husk. It has rather a strong beak suited for this purpose (Fig. 71).

The skull of the *blue heron* is also shown. These are aquatic birds, and their food comes from the bottom of the water, or in fact, down in the mud where they go after little frogs and little fish, and various other inhabitants of the water. Also is shown *passer domesticus* or *English sparrow*, which subsists on very much the same type of food as the crow, only it is a little more omnivorous, and the beak is very much the same. We also have the skull of a South American bird, the *toucan*, which is a fruit-eating bird. The serrations on the beak, which are useful in cutting through the skin of fruit and in sifting out the stones, will be noted as a rather interesting adaptation to the needs of this bird. Lastly, we see the skull of the *hawk*, one of the carnivorous birds. The beak of the hawk is very strong, and is used for the

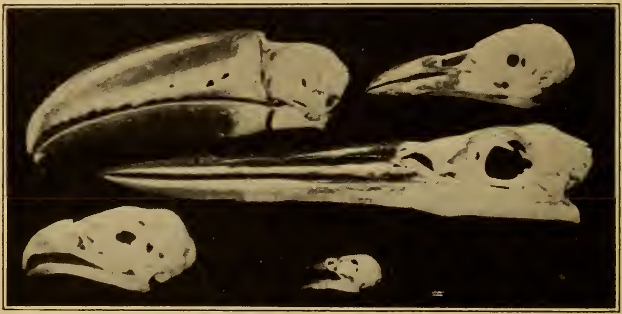

FIG. 71.—Beaks of birds showing functional modifications.

purpose of killing the prey: smaller birds, and mammals, in the case of large hawks, and insects and food of that sort in case of smaller hawks.

There is very much the same type of masticating apparatus, if it may be so called, in the *turtle*. Fig. 72 shows the skull of a large *green turtle*, the hawk-bill turtle, whose bill is covered with a very hard, dense mem-

FIG. 72.—Skull of a green turtle.

brane, which is very horn-like in quality, and is very much like the beak of birds, the purpose of it being purely to crush the food, and to cut off a definitely sized amount of food in order that it may be swallowed. Of course it it not possible for this animal to chew its food.

The first type of tooth that is of very great interest other than merely as a fang, or something of that sort, is the molar of the *ungulates* which are herbivorous and granivorous animals (Fig. 73). Herbivorous animals live on grain and on vegetable fiber, both of which require considerable trituration in order to be successfully acted upon by the digestive juices, solvents and ferments farther down in the digestive tract. For example, corn and other grains will pass down the alimentary tract of any of these animals entirely untouched unless the outer membrane is broken, therefore in order to be successfully digested they have to be well triturated.

The series of molar teeth of the horse is a real grinding machine. The surface is raised into elevations alternating with depressions. The elevations are the enamel, the depressions between, the cementum.

Fig. 73.—Skull of a sheep.

The cementum is very much softer, and as the tooth wears down the enamel which is harder and more resistant than the cementum wears much less rapidly, so that the surface is continually kept rough for grinding purposes.

This animal has a great latitude in the side-to-side movement of the jaw; or, to speak more technically, the lateral excursion of the mandible of herbivorous animals is very marked. The jaw does not move much backward and forward; in fact, it hardly moves in these directions at all, but it moves from side to side. The result is that these serrations run from front to back. This is exactly the reverse of the form of the molars found in the rodents, in which a backward-and-forward movement of the mandible is responsible for the grinding, necessitating a different arrangement of the occlusal surface of the teeth.

John Ryder, many years ago, pointed out the fact that from an examination of the surfaces of the molar teeth of any animal, extinct or living, he could without reference to the skull indicate the way in which the mandible was accustomed to move.

The front of the mouth of the horse is provided with incisor teeth which bite and pinch off the grass and other foods which the animal secures. The canine is quite rudimentary, and usually absent in the mare.

Cows have incisors only in the lower jaw, and the biting is done between the upper lip and the lower teeth.

Fig. 74.—Carnivorous and herbivorous skulls.

Now passing over one or two important orders as not being especially interesting, next comes a very large family in the animal kingdom, the *carnivorous* animals, which differ from the class just described in the character of their teeth and also in the manner of the movement of the mandible. In studying these dentures three fundamental elements and their relationship must be constantly borne in mind; the food supply, the teeth, and the manner in which the mandible is capable of moving.

For a comparison of dentures the skulls of a large western cat and of an ordinary buck sheep are pictured together (Fig. 74). A vast difference in the grinding teeth, as shown in their respective mandibles, is noted. In one the teeth are narrow, in the other the teeth are wide. Viewed from the side it is seen that the carnivorous molars have sharp edges and are rather more like knives than the grinders of the herbivorous series. In one there are very pronounced canines.

There is a very marked difference in the temporomandibular articulation of these two animals. In the case of the herbivorous animals there are broad, flat glenoid fossæ to render possible the large range of lateral excursion of the mandible. On the other hand, the carnivorous animals have no lateral excursion. The condyles fit into the fossæ so tightly as to make almost a hinge joint; and in some instances the distal part of the eminentia articularis so far overhangs its glenoid fossa that it cannot be seen. It is only with great difficulty that the condyles can be gotten out of these fossæ; indeed in some instances they cannot be gotten out without breaking the skull.

Fig. 75.—Skull of a tiger.

In the skull of an Indian tiger, it may be noticed that the molar teeth are of the type described (Fig. 75). They are very sharp, and there are tubercles on each side just before the cingulum is reached, and in the closure of the mouth the teeth pass by each other very much like the blades of a pair of shears. Besides the articulation of the mandible which serves to keep it in line, the upper canines fit into the spaces back of the lower canines and, locking the occlusion like guide-pins, prevent lateral movement.

The carnivora have greater crushing power in their jaws in comparison to their size than any other animals. This is partly due to the tremendous temporal muscles which are attached to the broad temporal ridges.

In the skull of a *black bear* is observed almost the same type of dentition as that of the cats, only the canine teeth are a little less powerful, and the carnassial teeth at the rear are not so strongly marked (Fig. 76).

A typical carnivorous dentition is found in the *caninæ* or *dog* family, and in a skull of the *canis latrans* illustrated are shown the several types

FIG. 76.—Skull of a black bear.

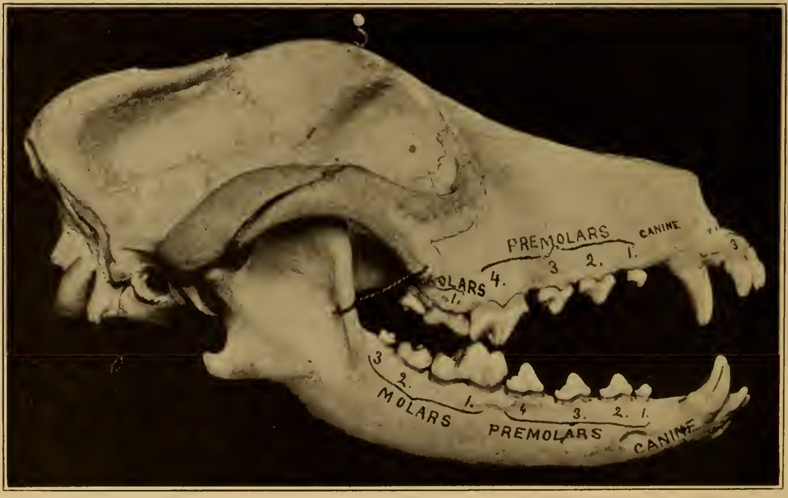

FIG. 77.—Skull of a coyote.

of teeth definitely marked; the incisors, three on each side, the canines, the premolars and the molars (Fig. 77). In the upper jaw there are four premolars and two molars, whereas in the lower jaw there are three molars and four premolars. The fourth upper premolar and the first lower molar are known as the carnassial teeth and they are the chief cutting teeth of these animals.

In the wolf and the American fox the dentition is precisely the same. In some of the smaller carnivorous animals, the badger, the otter, and the raccoon, the dentition is very much the same.

The next family is the *rodents,* who have a highly developed type of incisor. Thus far attention has been given chiefly to the molar teeth. In the rodents the incisor teeth are of the greater importance. In the skull of the beaver the upper incisor tooth has a chisel-like beveled edge (Fig. 78). It has enamel only upon its labial surface, which is supported by the dentin. There is no enamel on the back of the tooth. As the dentin wears away the enamel is left standing and chips away and thus always preserves a sharp edge. It is really a self-sharpening tool. It has a persistent pulp and grows out as it is worn off.

Fig. 78.—Skulls of rodents.

The rodents have practically no lateral motion to the mandible, but great backward-and-forward movement. Their molars are ridged, but the ridges run transversely, so that in the backward-and-forward movement of the mandible they can do the same kind of grinding as the herbivorous animals do in the lateral movement (Fig. 79).

Approaching nearer to man in the scale of animal life, as for example in the apes, dentures are found which are approximately like the human one. Thus in the *new world monkeys* (Fig. 80) almost exactly the same type of denture is observed as that of man, except that there are three premolars instead of two. There are two incisors, a canine, three premolars and three molars on each side.

The old world monkey is the first animal representing exactly the dental formula of man (Fig. 81). The three molars, the two premolars, the canines and the incisors are the same. There is, however, a space between the upper lateral incisor and the canine which is to admit the lower canine. These animals are largely frugivorous, and their teeth are suitable for this diet.

FIG. 79.—Skulls of rodents showing transverse ridges in molar teeth.

FIG. 80.—Skull of a new world monkey.

The *baboon* has very long teeth and exactly the same dentition as has been seen before, that is, it has the same formula. The molar teeth are very much the same in general form as the human molars. The chimpanzee has a deciduous denture which is even more like that

FIG. 81.—Skull of an old world monkey.

FIG 82.—Skull of a chimpanzee showing deciduous denture.

of man (Fig. 82). The gorilla has a very powerful mandible and the canines are very strongly developed.

It is not such a very long step from the dentures of the anthropoid apes to one of the lower types of human denture (Fig. 83). The skull shown is not of the lowest aboriginal type, but the highly developed jaws will be noted while the skull case which contains the brain is not highly developed.

Secondary Functions of the Teeth.—It might be interesting to dwell for a moment upon certain secondary functions developed in connec-

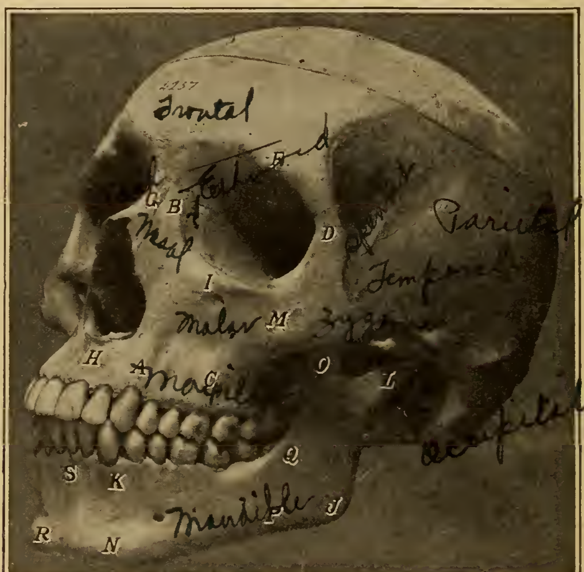

Fig. 83.—Architectural construction of skeletal portion of masticating apparatus: the fixed base, and moveable arm. Columns, arches, and buttresses of the fixed base; frontonasal column, *A B;* zygomatic column, *C M D;* pterygoid column (only partly visible), supra-orbital arch, *B F D;* infra-orbital arch, *B I D;* upper nasal half-arch, *B G;* palatal arch (not shown); lower nasal arch, *A H;* large molar arch, *A C;* molar buttresses (descending from *M*); pterygoid arches (not shown). Columns and arches of the moveable arm; mental column, *N K;* coronoid column, *P Q O;* and condyloid column, *J L;* external oblique column, *Q N.* (From a photograph of specimen No. 4237, Wistar Institute of Anatomy.) (Turner.)

tion with the teeth. Since secondary functions are performed by the teeth of man, those we find in the animals may be briefly viewed.

They are used as weapons of offence, as in the poison fangs of the snake, which is a very well-known example. The hypodermic needle really had its origin in the poison fang of the viperine snakes, a tooth with a tube extending through its center and leading to the poison sac. Upon the contraction of the digastric muscle and opening of the mouth the fang is erected, and when it is driven into the prey the sac at its base is compressed and the poison injected.

The *sword-fish* has a very dangerous projection which it uses to open the abdomen of fish from beneath and thus kills them. The use of teeth as weapons in warfare is well known, as in the *rhinoceros* and even our domestic animal, the *horse*. The teeth are also used for purposes of transportation and locomotion. The *elephant* uses his tusks, which are very highly developed upper incisors, to uproot trees, and dig up tuberous roots. He is trained in India to use them for the purpose of transporting lumber, etc. The *walrus* uses his upper canine teeth to pull himself up on the ice, and also for digging in the mud and uncovering small fish, shell fish, etc., which he consumes. One of the most interesting of the secondary uses of the teeth is found in one of the *lemurs*. The *flying lemur* (galeopithecus volans) has curious incisor teeth, the lingual side of which is very much like the teeth of a comb, and this the animal uses to comb its fur.

Fig. 84.—Upper and lower teeth in occlusion. (From photograph of specimen in the Wistar Institute of Anatomy.)

The Human Dental Mechanism.—The human dental mechanism primarily has to do with the preparation of the food for subsequent stages in its digestion, and it is a very interesting apparatus viewed as a machine, created for this purpose. To better understand it, for purposes of study, it may be resolved into its various elements. In the first place it consists of a fixed base and a movable arm (Fig. 84). The fixed base is the upper jaw, and the movable arm is the lower jaw. It has been likened to a hammer and anvil turned upside down; but the metaphor of the fixed base and movable arm is a little more expressive. These two elements are equipped with teeth, the armament of the apparatus. Between these two elements extend the muscles which elevate the mandible and constitute the motive power of the machine. Ordinarily they are spoken of as the muscles of mastication; the *masseter,* the *temporal* and the two *pterygoids;* and then at the front end of the mandible are muscles attached to the genial tubercles to assist in lowering the mandible, the *digastric* and the *geniohyoid,* and the muscle which forms the floor of the mouth, the *mylohyoid.* This whole apparatus is found in the cavity of the mouth. The cheeks and the lips on the outside serve as the outer walls of the cavity which contains the food while it is being masticated. The tongue on the inside is actively engaged in keeping the food between the crushing surfaces, and assists the cheeks and lips in that way. The last element of the apparatus is the salivary glands, the secretions of which have both a mechanical and physiological function. They lubricate the machine, soften and dissolve the food, and agglutinate it for deglutition, besides performing a digestive function in connection with the food.

The several portions of the apparatus will be taken up and discussed a little more in detail. The fixed base, which is the two maxillæ united in the median line, is supported upon the skull by a number of very strong columns or supports. It may be better seen if this base is considered as if it were upside down. There are several of these bony columns, one going inside the orbit and reaching the skull in the median line. (*A B,* Fig. 83.) There is another one from above the first or second molar going right up through the malar bones and the outer border of the eye (*C M D*). When the skull is viewed from below still another column is seen. This is the pterygoid, which supports the distal end of the dental arch.

The Mandible.—The lower jaw is the movable element, the movable arm. It has the general shape of the letter "U" and the ends of the "U" are bent upward at the end and terminate in the condyloid processes. There are several layers of soft tissues intervening at the joint which are placed there to lessen the shock of mastication, and permit the movement of the joint. Between this point and the anterior end the muscles of mastication are attached. They move the mandible as a lever, one end of which is fixed and constitutes the fulcrum. The muscles are attached between this end and what is the weight end of the lever, the forward portion which does the work. Thus it is a lever of the third class. The fulcrum exists in the tempomandibular joint which is interesting from a mechanical standpoint because it has so much to do with the way in which the mandible can move. The form of the glenoid fossa is a large factor in this. The jaw cannot move backward but it can move forward and downward until it is somewhere near the summit of the eminentia articularis. It can also rotate about a horizontal axis, passing approximately through the condyles. In considering the manner of movement of the mandible it will be seen how the joint renders these movements possible. Its movement is, of course, limited by ligaments. There is the *capsular* ligament which is thickened at the back into a very thick band, which prevents the jaw from going too far forward. The *external* and *internal lateral* ligaments are really nothing more or less than still greater thickenings of the capsular ligament itself on the outside and inside of the joint respectively which prevent the motion of the jaw laterally.

The other ligaments, the *stylomandibular* and *sphenomandibular,* which are largely thickenings of the cervical fascia, do not have very much to do with the way with which the mandible can move.

Of the muscular apparatus it is quite unnecessary to speak extensively. The *masseter* is the muscle most concerned in the elevation of the jaw, and the *temporal* and *internal pterygoid* aid in this movement. The function of the *external pterygoid* must be kept in mind in that it is attached to the *interarticular fibrocartilage* as well as to the neck of the condyle, and serves to pull them both forward in the forward movement of the jaw.

The direction in which the mandible can move may now be noted. First the simplest form of movement may be taken up, starting from that position of the mandible in which the teeth are in occlusion. This is the point toward which all the movements of mastication ultimately tend. With the teeth in occlusion, what happens when the mandible is depressed? The *external pterygoid muscle* on each side contracts and pulls its condyle downward and forward. The condyles slide down the walls of the glenoid fossæ. The *digastric* and *geniohyoid* muscles attached to the genial tubercles contract and pull down the front end of the mandible. The effect of these contractions is to carry the front end of the mandible down and the distal ends forward. The mandible does not rotate about a fixed axis, but the condyles are being carried forward at the same time that rotation is taking place. In other words, there is a combination of sliding and of rotation. When the mouth opens the condyles slide forward and downward, and the front end of the mandible is depressed. The mouth could not be opened if the condyles remained in the back part of the fossæ.

There is then a combination of rotation about a horizontal axis passing through the condyles and a sliding motion. It so happens that the front teeth describe what is approximately the arc of a circle while they are sliding and rotating; but the center of that circle is not in the condyles, but considerably back of them.

When the mandible is brought up again to the occlusal position the reverse of this takes place, but Tomes and Dolâmore have found out by tracing a large number of jaws that the path of closing is always a little bit in front of that of opening. Direct opening and closing is a type of movement seen in the carnivora. The condyles do not slide forward. In the herbivorous animal there is a lateral movement. In that lateral movement one condyle remains in the fossa and the other one slides downward, forward, and inward. This type of movement is also noted in the human jaw. One of the condyles remains in its fossa, the other one being pulled downward and forward by the contraction of the *external pterygoid* muscle of the side. Of course that means that the two pterygoid muscles are capable of independent contraction. The mandible rotates approximately about the center of the stationary condyle. The same occurs when the jaw moves to the other side, as it simply reverses the moving and the stationary condyles.

If both *external pterygoids* contract, the jaw is carried forward or protruded. If they contract independent of the muscles attached to the front end of the mandible there is a protrusion of the mandible. That is a type of movement characteristic to the rodents or the gnawing animals. There is then in the human jaw the possibility of these three distinct types of movements.

Now that the fixed base and the movable arm and the motive power of the apparatus, and the manner in which the mandible, or the movable element may be actuated have been described, the teeth will be discussed from the standpoint of their form and arrangement as suitable to the working of the machine.

A Study of the Human Denture.—In the first place the forms of human teeth are modified or fused cones, as are all animal teeth (Fig. 84). The incisors are cones with a flattened end and may be likened to the form of a chisel. This type of a tooth is especially well developed in the rodents. The canine tooth is more nearly a cone of simple form than any other, although not perfectly circular in cross-section. It is similar in general form to the canine teeth in the carnivora, more like them perhaps in a general way than that of any other animal types, the canine in the herbivora being either lacking or very rudimentary in character.

The bicuspids (the term being derived, of course, from their two-cusped or two-coned character) are, as has been indicated, merely two cones fused together.

The molars, on the other hand, have a number of cones fused together, each cone represented by a cusp; in case of the lower first molar normally five cusps, and the others only three or four.

The teeth are arranged in two arched series, consisting normally of thirty-two teeth, sixteen in each series (Figs. 85 and 86). The actual outline of this arch varies with individuals, but within certain bounds this variation in form has no relationship whatever to its functional efficiency.

The upper arch is larger and overhangs the lower. The upper teeth constitute the fixed base in relation with which the lower teeth move, therefore the upper arch would necessarily cover a larger area in order to permit the movement of the lower over its surface.

On the inside of the teeth is the tongue, on the outside the lips and cheeks. The overhang of the molar and bicuspid series in the rear, and of the incisors in the front of the mouth not only serve the useful purpose of providing a larger area over which the lower jaw may move, but it serves to hold the lips and teeth out of the way and prevents their being caught between the crushing surfaces. On the inside the fact that the lower teeth overlap and pass up the inner sides of the upper teeth serves a similar purpose of keeping the tongue out of the way.

FIG. 85.—Occlusal surfaces of the upper teeth.

One may realize how useful this provision is if one observes a set of artificial teeth in which this overhang is not properly provided, when the wearer will frequently complain that he bites his cheeks. Instances of the same difficulty are seen in mouths with full sets of natural teeth, the cusps of which have worn down, and in which the lower jaw has moved forward to what is designated an edge-to-edge bite. There is

FIG. 86.—Occlusal surfaces of the lower teeth.

no doubt of the authenticity of the reported case of a well-known man who lost his life through cancer originating in the irritation of the cheek from biting it when the cusps of his teeth had worn off until he had an edge-to-edge bite.

The series of teeth normally present an unbroken surface from one end around to the other; that is, there are no spaces between them, as in some of the animals, particularly the carnivorous animals. Man is the only animal not having diastemata, or spaces between his teeth. This is provided for by the bell-like shape of the crowns of the teeth which do not touch at their necks but at the point of interproximal contact. This contact serves to protect the gum tissue below from injury from the food such as meat and vegetable fibers. If one has experienced what it is in one's own denture to have a flat filling, or none at all, in consequence of which food packs in and produces the long train of uncomfortable results, one will understand how wise is this provision of nature.

Occlusion.—The occlusion of the teeth, to attempt a very offhand definition, is the relationship of their morsal surfaces when the mandible is in the position of the resting bite (Fig. 87). The phrase is used to indicate the relationship of the upper and lower teeth when in such contact that there is a definite fitting together of their surfaces. In the occlusal position the condyles of the mandible are in the most distal part of the glenoid fossæ. When the teeth are in occlusion the muscles extending between the jaws are either in a state of tonic contraction, simply holding the jaw up, or they may be actively contracted, that is, pressing the lower teeth firmly upon the upper ones. This is a rather fundamental position of the jaw. It is a position of equilibrium. It is to this position and from this position that all the various movements incident to mastication take place. In the crushing of the food the jaw tends to return from its various excursions to the occlusal position.

The occlusion of the teeth then means the definite relationship existing between the occlusal or morsal surfaces of the teeth. This must be carefully considered, for in order to understand the machine in motion it must first be studied in repose. Perhaps simplicity will be consulted by dividing the description of the occlusion into that of the incisor teeth, and that of the molar and bicuspid teeth.

As to the incisors, which are flat and wedge-shaped, the upper overhang the lower, the incisal edges of the lower resting normally in contact with the lingual or inside surfaces of the upper teeth. This normal overhang or overbite is approximately one-third of the length of the lower teeth, although of course it is subject to slight variation. The canine tooth is really intermediate in the character of its occlusion between the incisor and the bicuspid series. It partakes of the characteristics of the incisors in that it overhangs the lower teeth, but it is like the bicuspids in having a sharp cusp exactly like the buccal cusps of the bicuspids.

When the teeth have worn down either from having had a very small overbite and short cusps originally, or from the use of coarse food, so that there is an edge-to-edge bite, the machine is by no means as effective as in the arrangment referred to as normal. In the latter case the food is simply pinched off and not sheared off as when the upper incisors overhang.

In the study of the occlusion of the molar and bicuspid series of teeth the occlusal surfaces should be first considered (Figs. 85 and 86). It will be noted that they exhibit two rows of cones with depressions or fossæ intervening between them. On this surface of the bicuspids there is a cone on the inner and outer side. In studying the molars there will be found two cones on the inner and outer sides, except on the third molar where the distolingual cusp may be lacking.

There are then a row of inner and a row of outer cones, with fossæ or little pits intervening between them. There are transverse ridges dividing one fossa from another. The same thing is true of the occlusal surfaces of the lower series of teeth. They have a definite arrangement, a row of outer and a row of inner cusps with fossæ between. However, there is a difference in the shape in these two rows of cusps. The inner ones are rounded in the upper series of teeth and are considerably larger than those in the outer row. Speaking technically, the lingual are larger than the buccal cusps, which are sharp and thin, while the reverse of this is true of the lower teeth. The buccal cusps, or outer cones, are the large round ones; the inner cusps are sharp and thin. The rounded cusps in both series are really the functionating cusps. They are the ones which are received into the fossæ when the teeth are in the occlusal position. If an upper set of teeth is superposed upon a lower, it will be found that the lower buccal cusps occupy the fossæ of the upper series and the rounded lingual cusps of the upper fit into the fossæ in the lower set of teeth.

It is not enough in the normal arrangement that any cusp should fit into any fossa. In normal occlusion there is a definite fossa for each cusp to occupy (Fig. 87). Orthodontists have accepted a simple method of determining when a denture is in normal occlusion. They look to see if the mesiobuccal cusp of the first upper molar occupies the buccal groove of the first lower molar and if so and the other cusps fit into their fossæ, and so on, then the occlusion is correct. If this cusp is in front of or back of the buccal groove then it would not be normal occlusion; there might be an interdigitation of the cusps but it would not be perfectly normal, unless each cusp occupied its own particular fossa.

In an inner view of the denture (Fig. 88), the overlapping of the sharp and thin inner cusps of the lower teeth will be noted, each fitting into a groove or space on the lingual surfaces of the upper teeth. This interdigitation has also another rather interesting advantage, and this is that each tooth of both series, with two exceptions, is opposed by two teeth in the opposite jaw. They do not meet end on end, but each tooth is in relation to two teeth. The exceptions are the upper third molar and the lower central incisor which have but one opponent each (Fig. 89).

Fig. 87.—Occlusion of the molar and bicuspid teeth, external view. (From photograph of a specimen in possession of Dr. F. A. Peeso.)

Fig. 88.—Occlusion of the molar and bicuspid teeth, internal view. (From photograph of a specimen in possession of Dr. F. A. Peeso.)

Now that the relationship of the morsal or occlusal surfaces of the teeth in the position of occlusion has been described, it will often be referred to as the occlusion of the teeth.

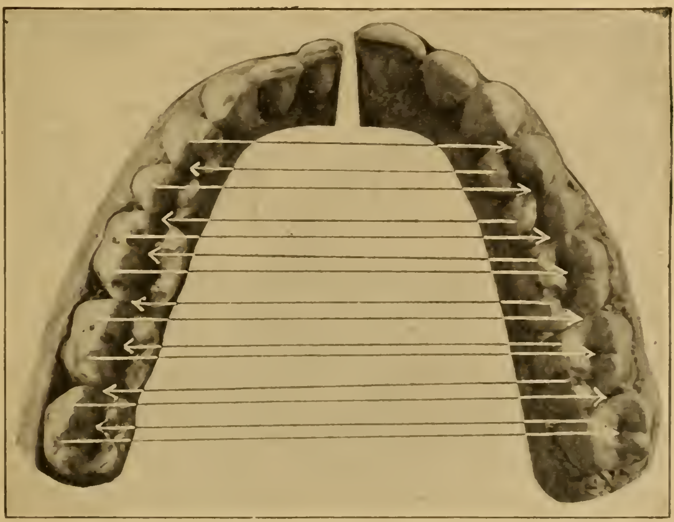

FIG. 89.—Occlusion of the molar and bicuspid teeth, occlusal view. Lines are drawn from the lingual cusps of the upper teeth and buccal cusps of the lower to the corresponding depressions into which they fit. (From photograph of a specimen in possession of Dr. F. A. Peeso.)

There are certain other characteristics of the arrangement of the occlusal surfaces of the teeth which are related to what shall be spoken

FIG. 90.—The "Curve of Spee." Line passing through anterior face of condyle. (From a photograph of a specimen in the Wistar Institute of Anatomy.)

of as the articulating or active relations of the denture that will be useful when the denture is in motion. One of these characteristics, which is a very important part in the so-called articulation of the teeth, is as follows: If an imaginary line were drawn touching the buccal cusps of the lower series of teeth in a perfect denture, it would be found that they described approximately the arc of a circle, and if it is continued backward under a perfectly typical arrangement, it passes just anterior to the articulating face of the condyle (Fig. 90). Sometimes this line may go a little in front of it, more frequently it is back of the condyle; in a perfect arrangement it passes through the anterior face of the condyle. The same thing is necessarily true of the upper teeth. This is called the curve of Spee. It has been named after von Spee who first called attention to it. This curved arrangement of the occlusal surfaces of the molar and bicuspid teeth has an important bearing on the movement of the mandible.

If two surfaces are to slide one upon the other without interrupting their contact at any point, that is, without being separated at any point, these must be either two perfectly flat surfaces like two panes of plate glass, where one can slide upon the other without admitting air underneath, or else two curved surfaces which are the arcs of the same circle. If they were any other shape, as for example, a parabola or hyperbola, or any irregular curve, they would separate at some point. Now if it were desirable that in the forward-and-backward movement of the mandible all of the lower teeth should slide upon all of the upper at the same time, then these teeth would have to be either in a perfectly plane surface, all absolutely level, or they would have to be arranged around the arc of a circle.

In order to get a clearer understanding of this, it may be supposed that there are no cusps upon the occlusal surfaces and that a curved line represents the top surface of the lower teeth, and a similar curved line represents the occlusal surfaces of the upper teeth. Now if these surfaces are to slide upon each other, without breaking their contact, in the case of the human jaw the mandibular condyles, which of course slide upon the glenoid fossæ, would have to slide in exactly that same curve, otherwise the teeth would be separated at some point.

Now this is the significance of this arrangement of the teeth, that the so-called curve of Spee is always either continuous with the path of the condyle, or it is concentric with it; at any rate they can both move around the same center. This, it must be remembered, is merely a very much simplified example taken to explain the principle involved. These are not plane surfaces, but are cuspid surfaces, and each one of these cusps fits into a fossa. However, it does not take a very great stretch of imagination to see that, though they have cuspid surfaces, the cusps may be arranged so that instead of sliding upon a smooth surface they slide upon the walls of the fossæ into which they fit. That it is possible to have such an arrangement may be conceived and this is the arrangement in the perfectly typical and typal human denture. Of course the mandible has to be depressed the least bit in order to enable each cusp to slide downward on the front wall of the fossa into which it fits. The cusps slide forward on the walls of the fossæ and back again; and the advantage of this is that every one of the cusps is functionating, is in contact at the same time, not just hitting here or there. But it is possible for a denture to functionate in this fashion only if the teeth are arranged in the manner described.

It will presently be seen, however, that the lower teeth of a normal typical denture cannot slide very far forward without the teeth separating, because the lower incisors strike the lingual surfaces of the upper incisors. After the cusps have moved perhaps half-way up the walls of the fossæ into which they fit, the lower front teeth strike the upper

Fig. 91.—Upper and lower bicuspid and molar teeth (side view), showing relative height of buccal and lingual cusps of upper teeth. (From photograph of a specimen in the Wistar Institute of Anatomy.)

incisors upon which they slide and the distal teeth are separated. But in the return movement, when the lower teeth strike the lingual surface of the upper and slide up until the distal teeth are in contact and then slide back into the occlusal position, each one of the cusps then slides back down the wall of its fossa into the position of the occlusion.

There is another characteristic of the arrangement of the molar and bicuspid teeth which is related to the lateral excursion of the jaw. Taking a typically perfect set of teeth with the jaws slightly apart, it will be seen that, starting from the first upper bicuspid and going toward the rear, the buccal or outer cusps become relatively a little bit shorter than the lingual cusps and, in the case of the lower teeth, they become a little longer than the lingual cusps. Of the second bicuspid in the upper jaw, the buccal and lingual cusps normally occupy the same horizontal plane. Just in front of it the first bicuspid has a buccal cusp that is longer than the lingual. Returning to the first molar, the buccal cusps are a little shorter than the lingual, and going back farther and farther, they get relatively shorter than the lingual. In other words, the plane of the cusps, instead of being level, gradually curves rootword and outward toward the rear of the denture (Fig. 91).

This arrangement can be demonstrated in the mandible although the first bicuspid has a rudimentary cusp or none at all and is atypical in

Fig. 92.—Lower bicuspid and molar teeth, front view, showing relative height of buccal and lingual cusps. Same mandible as Fig. 91. (From photograph of a specimen in the Wistar Institute of Anatomy.)

this particular; but farther back the buccal cusps are relatively higher than the lingual until at the third molar they are considerably higher (Fig. 92).

In looking at the upper teeth this characteristic may not be so well illustrated as in the lower jaw, but a gradual tilting out of the long axes of the teeth will be noted. This arrangement is due not only to the height of the cusps, but to a change in the inclination of the teeth. The second bicuspid occupies a perpendicular position; but the teeth back of it gradually tilt outward.

Now what is the relationship of this arrangement to the lateral excursion of the lower jaw? When the mandible is moved to one side with the teeth in contact, if the teeth were arranged so that their cusps occupied the same horizontal plane those on one side would be separated while those on the other side would be in contact. The reason for this is that when the mandible is carried to one side one condyle remains stationary in its fossa while the other is pulled forward and also downward as the surface of the glenoid fossa inclines downward and this side of the jaw must be carried a little lower than the side with the stationary condyle.

If it were not for this difference in the level of the buccal and lingual cusps there would be a lack of contact on the side from which the movement was taking place. In order to compensate for this lowering of the mandible on the side from which the movement has taken place, the two longest or most prominent cusps come into contact; whereas on the other side, the side toward which the movement has taken place, there is a short and a long cusp in contact; and it is just the difference between these two which compensates for the downward movement of the jaw on the side from which the movement has occurred (Fig. 93).

FIG. 93.—Diagram illustrating contact of cusps in lateral excursion of the mandible. Section through jaws at position of second molar. *O P*, line touching lingual cusps of upper molars; *L R*, line touching buccal cusps of upper molars; *S T*, line touching buccal cusps of lower molars, showing the downward movement of the mandible on the right side necessary for contact of the cusps.

What is the advantage of this arrangment? It has exactly the same functional advantage in the lateral excursion of the mandible as the curve of Spee affords in the forward and backward excursion of the jaw; that is to say, it enables both sides to be in contact at the same time. This principle is taken advantage of in making artificial dentures. If both sides of the plates were not in contact at the same time, so that the patient was biting foods on one side with the other side not touching at all, the plates would be thrown down from their base. So it is desirable to imitate the human denture in this particular because it prevents overstrain, and provides a denture that is more efficient mechanically.

There is one other detail of the occlusal surfaces of these teeth relating to their function which must be mentioned and this is, that clearance spaces are provided for the escape of food which has been masticated. The upper row of buccal cusps overhangs the lower, and on the outer walls of all of these fossæ, into which the lower buccal cusps fit, are grooves leading downward and outward through which the food is squeezed. Anyone operating a cutting or grinding machine of any kind will realize the necessity of getting rid of the waste or the chip, as the mechanical terminology is. That is, after the substance has been crushed or ground, there must be an avenue of escape for the waste, and so these grooves, which are not visible on the side view, but which lead downward on the outside of the arch, and upward on the inside, are provided. When the food is crushed between these surfaces it is carried up above the tongue on the inside and downward into the pocket of the cheek on the outside where it may be pressed between the teeth when they are separated for the next crushing motion.

Mastication of Food.—Having described the machine, its mode of operation may now be considered. In the case of man the preparation of food in the mouth does not begin with prehension or gripping of the food, as it does in most of the lower animals. Man has, of course, developed very much beyond that point, and there is no necessity for it. There is no provision for this in his denture therefore, and he has no sharp teeth to prehend the food. The first act of the human animal is to incise; but even incision or the cutting off of appropriately sized particles of food is largely rudimentary in man, since with the development of conventional methods of eating, bringing into use the knife and fork, the incisior teeth are not much exercised. The biting of certain articles of food only is permitted by the usages of polite society. But when incision is indulged in it is rather an interesting mechanical act. The lower jaw is depressed and carried forward, the food is pressed between the lips and upon the incisal edges of the upper teeth, when the lower jaw is carried upward. If the food is very hard, the ends of the upper and lower teeth are almost exactly opposite each other. This direct opposition is absolutely necessary from a mechanical standpoint, in order to bite through hard, resistant food. As soon, however, as the teeth come into contact, or nearly into contact, the mandible is carried backward as well as upward, and the lower incisors slide up the inner surface of the upper, just like the blades of a pair of shears. Then the food is carried back by the tongue to the distal part of the mouth.

In order to understand clearly just what is demanded during trituration of the food, it will be wise to refer again to the importance of a knowledge of the character of the food itself. Its chemical nature is not of so much interest as its physical character viewed purely from a mechanical standpoint. Man's food, broadly speaking, consists of meat fiber, vegetable fiber, grain or cereals and foods made from them, and legumes, although the last is not of the same importance as the others. The chief articles which must be prepared for digestion are vegetable and meat fibers, cereals or grain. It is necessary to reduce this food to a condition suitable for passage into the stomach. Its physical consistence must be reduced that it can be acted upon by the digestive ferments and solvents. The crushing of grain, the starchy element of man's food must be very much more extensive than is necessary for the other elements. In the first place, its outer covering has to be removed, or at least broken, and the grains of starch themselves must be so ground up that they can be acted upon by the enzyme of the mouth, and by those farther down in the digestive tract. Mastication of cereals and foods made from them is therefore really much more important than the mastication of other foods.

Baron Oefele has conducted some investigations to show the very poor ability to digest cereals exhibited by people who do not have a full complement of molar and bicuspid teeth. His results are very interesting, but it is only necessary for our purpose to state the fact that he has very conclusively shown the defective digestion of cereals by those whose molar and bicuspid teeth are defective.

Vegetable fibers must be cut up into short lengths and crushed so that they can be readily acted upon by the solvents and digestive ferments. This is more important than the comminution of meat fibers. Many carnivorous animals eat animal flesh in great masses; carnivorous snakes always swallow their prey whole. Nevertheless it is important that meats should be masticated by man in order to break up the consistence of the fiber, and also it should be cut up into small masses to facilitate its passage through the digestive tract and that it may be readily acted upon by the enzymes and ferments.

Dr. Black, who has investigated quite extensively the problem of the mastication of the various kinds of foods, is authority for the statement that the up-and-down movements of the jaw, very much like those of the carnivorous animals, are chiefly concerned in the mastication of meats, and that the lateral movements are chiefly concerned in the mastication of cereals and foods made from them.

While it is not true that in the masticating of any type of food one is limited to any particular type of movement, it is a fact that the foods which require the greatest amount of crushing force are masticated in the return from the lateral excursion of the mandible.

When the cereal food is brought into the mouth and carried back to the molar and bicuspid teeth, mastication usually occurs on one side at a time; and if the mouth is in a state of balance and perfect health, it is very apt to occur first on one side and then on the other. The mandible is carried to one side, the cusps are brought into contact, some of the food being cut off on the outside and some on the inside, but a mass remains which occupies the space between the cusps and in the fossæ and on the return to the position of occlusion the cusps slide, into the fossæ with a sort of mortar-and-pestle effect. In this movement the greatest crushing ability is exhibited. In ordinary mastication this lateral movement is combined with direct up-and-down movement. Mastication is not carried on in any precise mechanical order, but all of the movements are combined at times.

Dr. Black has also made in this connection what is rather an interesting table of the amount of force necessary to crush the various foodstuffs. Dr. Joseph Head, of Philadelphia, has also produced a similar table, though using a different method, and the two will be presented together. Dr. Black's experiments were most interesting. He had some brass castings made of the molar and bicuspid series of teeth, upper and lower, and had them arranged in a machine so that the lower could be brought up into contact with the upper by the movement of a hand lever: This simply had the up-and-down motion. He and a party of friends went at various times to restaurants in Chicago, and while they were dining themselves, they gave this automatic chewing machine various tidbits, and registered on it, as they could not on their own jaws, the amount of force necessary to crush the various foodstuffs.

Dr. Head, realizing the value of the lateral excursion, and believing that much less force was required in the crushing of food with this type of movement, made experiments similar to those of Dr. Black, except that he took a human skull with a fine set of teeth and turned it upside down, bored a hole through the skull, and suspended weights from the mandible by means of string or wire. He proved that to accomplish the same amount of crushing, less force was required in this lateral sliding movement. Dr. Black's and Dr. Head's tables are here given.

	Dr. Head's results.	Dr. Black's results.
Raw cabbage	16	40–60
Raw onion	4	
Head lettuce	8	25–30
Radish—whole	20–25	
Radish—pieces	10–25	35–40
Corned beef	18–20	30–35
Boiled beef	3	
Tongue	1–2	3–5
Lamb chops	16–20	
Roast lamb	4	
Roast lamb kidney	3	
Tenderloin of beefsteak (very tender)	8–9	35–40
Sirloin steak	10–20–43	
Round of beefsteak (tough)	38–42	60–80
Roast beef	20–35	35–50
Boiled ham	10–14	40–60
Pork chops	10–13	
Roast veal	16	35–40
Veal chops	12	
Roast mutton	18–22	
Very tough meats	...	90
Hard crusts	...	100
Hard candy	...	250

Dr. Black also experimented with a gnathodynamometer by means of which he could measure the strength exerted by the human dental mechanism, which for the average was from 150 to 175 pounds. He reported one case in which 275 pounds were recorded on the instrument. He also tried it with persons wearing full artificial dentures, upper and lower, the result being that the average was from 35 to 40 pounds. One may see a vast difference in the amount of crushing ability of natural and artificial teeth.

Mastication is of course a voluntary act (speaking physiologically), that is, it begins voluntarily and is continued reflexly and automatically. The food is rolled from one side to the other by the tongue. The teeth functionate first on one side and then on the other. The teeth have exquisite sensibility. It is through them that sensations are received that indicate the amount of chewing necessary to give any given mouthful, and also through them in conjunction with the tongue as to whether the food has been thoroughly triturated or not. After it has been thoroughly masticated it is rolled up into a bolus on the tongue, the tip of which is elevated, and by contraction of the muscle of the floor of the mouth, the mylohyoid, the food is forced back into the esophagus.

The secretion of the saliva, while constantly going on in the mouth, is tremendously increased when any foreign substance, like food, is put into the mouth. The working of the muscles moving the jaw probably also increase the flow of saliva. The saliva serves to lubricate the various portions of the apparatus which are in the mouth. It contains a ferment, ptyalin, which has some digestive usefulness. The water in the saliva dissolves some of the food, and as it also contains mucin, the latter helps to agglomerate the mass and to lubricate it so that it is finally easily swallowed.

The teeth are equipped with means of resisting the wear incident to the activity of this mechanism. The enamel is the outer envelope of the crowns of the teeth and is the hardest structure in the human body. It is of course necessary to have a very hard covering for the teeth to enable them to resist the wear incident to their long use. Under present conditions of civilization, where comparatively little mastication is necessary, not a great deal of wear of the teeth occurs. The teeth of prehistoric man, and, indeed, of our own aboriginal races, wore very badly from the coarse character of the food. Any collection of skulls of North American Indians which one may happen to see at once impresses one with the great amount of wear of these teeth. Of course this is due, not only to the rough character of the food, but also to the fact that Indian corn, a staple diet, being ground in stone mortars had fine particles of stone or silica mixed with it, which serve to grind the teeth down.

Anatomists have recognized several degrees of wear. No one reaches the age of twenty-five without beginning to show some evidence of wear of the teeth. A little later the second degree is reached, where the enamel is worn through and the dentin exposed, and the cusps are really beginning to wear down a little; or it may even, under conditions of our civilization, get to the third degree, where the cusps are all worn away, and the teeth are reduced in height.

Mastication has also a beneficial influence upon the teeth. The friction of the food exerts a cleansing influence as regards colonies of bacteria and deleterious food particles upon their surface. Disuse of the teeth on the other hand, greatly increases the deposits of salivary calculus and sordes upon the teeth. Often upon looking into a mouth it is perfectly easy to judge upon which side a crippled tooth exists, because when the chewing is done on the other side, exclusively, deposits on the teeth of the crippled side identify it.

The use of the denture in mastication also exercises the peridental membrane. As the teeth move up and down in their sockets, blood is pumped in and out of this tissue and thus it is kept in a healthy condition and degeneration of the pericementum is deferred if not prevented.

Supplementary Functions of the Teeth.—In conclusion, certain secondary functions of the teeth will be briefly considered. They participate

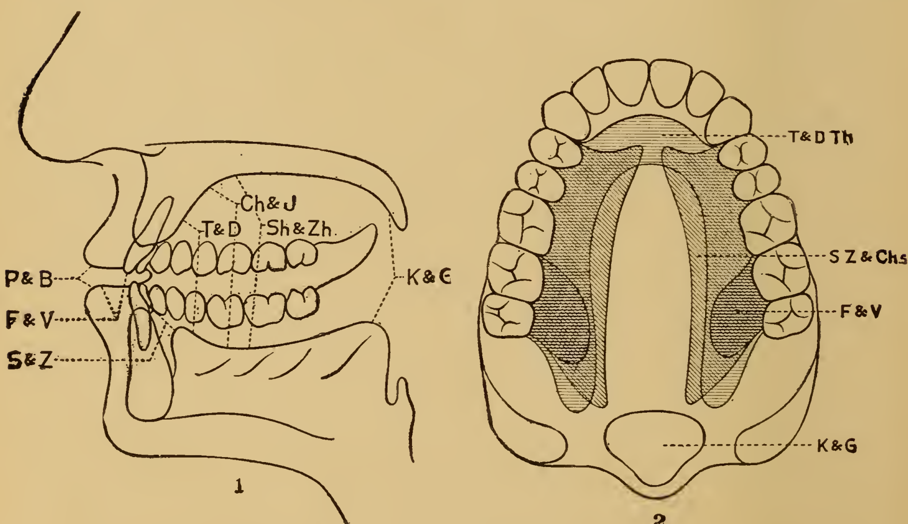

Fig. 94.—*1*, diagrammatic drawing showing place of articulation of the consonant sounds; *2*, drawing showing contact of the tongue with molars and bicuspids in the formation of certain consonants.

in the activity of the mechanism concerned in the production of speech. The lips and tongue with the teeth and the contiguous portions of the alveolar process are the most important factors in the production of consonant sounds. Thus the "F" and "V" sounds, for example, are pronounced by the sudden escape of air between the lower lip and the upper front teeth. It is unnecessary to go into this detail at length, but an allusion is made to it as an additional reason for care in the preservation of the teeth (Fig. 94).

They are also passive elements in the mechanism concerned with the facial movements of expression, which are movements of the facial muscles that either supplement language or convey ideas or emotions or states of mind.

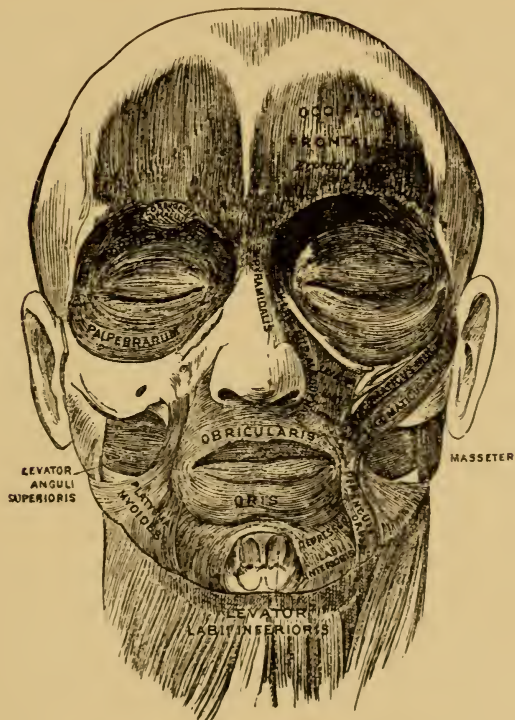

Fig. 95.—The facial muscles of expression.

Fig. 96.—Photograph showing effect of the loss of the teeth upon the mouth, and wrinkles established thereby.

Fig. 97.—Photograph showing the effects of the loss of the teeth upon the profile.

The underlying structures in this mechanism are the skull and the teeth, overlying which are soft tissues including the facial muscles of expression. There is a large group of these centering around the mouth which makes it one of the most expressive features of the face. These muscles are superficial, converge toward the mouth and terminate in one big muscle, the orbicularis oris, of which latter the lips are chiefly composed. These are all supported beneath by the teeth and the alveolar process, over which as a sort of base they are moved by these various muscles. In some of these movements the lips are parted so that the teeth are disclosed. Both pleasurable and painful emotions may be so expressed (Fig. 95).

Finally the teeth serve to support the lips and the cheeks and thus take part in the maintenance of the fixed expression of the face. Their loss is attended by a falling in of these tissues, an approximation of the jaws, and by a marked change in the appearance in the face. To guard against this "last scene of all" is the final reason for their preservation (Figs. 96 and 97).

CHAPTER IX.

MALOCCLUSION OF THE TEETH

By RODRIGUES OTTOLENGUI, M.D.S., D.D.S., LL.D.

If the mouth hygienist, besides preserving the health of her charge, would aim likewise to guard against the attacks of disease, it is evident that she should have knowledge of such diseases as may prove a menace in her particular field of work, and she should likewise learn to recognize these diseases in their incipient stages that she may refer the patient for treatment before the ravages prove serious.

Therefore, in presenting the subject of malocclusion, let us consider for a moment how dental caries is aggravated by irregular or maloccluded teeth.

DENTAL CARIES

Areas of Susceptibility.—Students of the subject tell us that in the vast majority of cases caries begins in certain definite localities. Thus caries upon the masticating surfaces of bicuspids and molars first appears in the sulci or fissures between the enamel plates. Between the teeth or, as we say, on the approximal surfaces, caries has its initiation at, or just gingival to, the approximal contact points. While it may not be absolutely true that "a clean tooth never decays," it is true that an unclean tooth is more vulnerable than one that is clean. It follows, therefore, that the unclean or uncleansable parts of a tooth are more likely to decay than the clean or readily cleansable parts of a tooth, and this is in consonance with the statements above made as to the locations where caries usually begins, because the sulci of molars and bicuspids, and the approximal contact points of all teeth, are the localities in which food débris is most apt to lodge and most difficult to dislodge. Another region in which caries often occurs is upon the labial and buccal surfaces of teeth immediately near the gum line. Here the seepage of mucus agglutinizes the food débris and the overhanging gum margins protect the accumulations from the natural cleansing agents. Still another place is in the grooves on the buccal surfaces of the molars, which are analogous with the sulci upon the masticating surfaces. These, then, are to be counted the vulnerable places.

Areas of Immunity.—The lingual surfaces of all the teeth, swept as they are by the tongue, constitute the most immune areas, though occasionally we find pits or crevices in the upper incisors, which because they are pits or crevices become susceptible points. The labial surfaces of all incisors and cuspids, except at or along the gum margins, and the buccal surfaces of all molars, except in the buccal grooves, are practically immune to caries.

So we find that there are certain localities which are vulnerable and other definite parts of the tooth which are practically immune to caries. Also, that this immunity is closely related to the possibility of cleansing these areas.

Between these vulnerable and immune locations are areas of comparative immunity, this comparative immunity increasing toward the immune or most easily cleansed part, and decreasing as we approach the vulnerable or less easily cleansed part.

Caries and Malocclusion.—Thus we arrive at the important relation between malocclusion and caries. We have seen that certain parts of the teeth are counted to be immune to caries, and that adjacent to these areas are other parts which are comparatively immune. But this is true only when all the teeth are in normal relationship one with the other, which in effect means when all the teeth are in normal occlusion.

Malocclusion may not perhaps often increase the vulnerability of the occlusal surfaces of the teeth, though at times it may even have this effect; but malposition of the teeth will frequently increase the vulnerable approximal areas by increasing the contactual areas beyond the normal; and it will likewise lessen the immunity of the immune and comparatively immune areas, by rendering cleansing more difficult and at times even impossible.

We will better comprehend this by the examination of a skull where we may see the teeth and bones freed from the soft tissues.

Interproximal Spaces. Fig. 98 affords a good example of normally occluded teeth, one maxilla and one-half of the mandible with their teeth being shown. Attention should be called first to the spaces between the teeth known as interproximal spaces. Note that these are, generally speaking, triangular in shape, the base of the triangle being along the border of the alveolar bone, the sides of the triangle being the approximal surfaces of the adjacent teeth, and the apex at the point of contact of the two teeth. Select any approximal space distal of the cuspids and note that the apex of the cusp of the antagonizing tooth of the opposing jaw falls immediately opposite the center of this interproximal space, the obvious tendency being to force food between the teeth, and into this interproximal space. Hence the need of the contact point. Passing from the study of these bones and examining a living specimen, we would observe that this interproximal space is filled with gum tissue, this particular part of the gum being denominated the septum. This septum, filling as it does a triangular space, is conical in shape and is thicker than other parts of the gum. For this reason its outer surface is farther away from its bony support and consequently it is more easily injured than the gum elsewhere. This is an added need for close contact of the adjacent teeth, as a protection to this sensitive tissue from the impaction of food and the retention of it, if forced into the interproximal space. The student should note also that the gum septum, also called the gingiva, even in the healthiest subject, does not entirely fill the interproximal space, so that commonly there is a small but actual space between the approximal contact points and the septum or gingiva. It is because of this fact that approximal caries often has its inception just gingivally of the contact point, since it is just in this space which is protected from the natural cleansing agencies that débris may collect and remain.

If we study the matter more closely still, we must see that wise provision has been made for the exclusion of foodstuffs from the inter-

Fig. 98.—Occlusion of the molar and bicuspid teeth, external view. (From photograph of a specimen in possession of Dr. F. A. Peeso.)

proximal spaces. True the grinding cusps of the masticating teeth, falling as they do exactly opposite to the entrances to the interproximal spaces, would seem to be advantageously situated for the forcing of food into these spaces, yet this accident is well guarded against. First we find that the cusps in typically formed teeth occlude against the mesial and distal marginal ridges of the two teeth with which each cusp normally antagonizes. These marginal ridges have planes sloping toward the central portions of the masticating surfaces, and hence away from the interproximal space.

Moreover we find sulci serving as sluiceways to lead the food, during maceration, lingually and buccally away from the spaces between the teeth, and consequently it should require more force to crowd the food into the interproximal spaces than away from them into and out of the sluiceways. Additional protection of the gingivæ is to be found in the form and position of the contacts, as well as in the form of the septum itself. The contacts are closest occlusally and triangular in shape so that the width of the contacts increase slightly toward the gingiva, while the approximal surfaces of the teeth, curving rapidly apart, afford ample opportunity for the escape of food, especially as the septum itself is conical and full enough buccolingually to extend somewhat beyond the actual interproximal space and thus aid in receiving and carrying the food away from, rather than into, the space.

All this may seem somewhat complex, whereas in reality when once fully comprehended, it will be seen to be quite simple and as admirable an arrangement as it is a simple one. Yet its efficiency depends entirely upon and is proportional with its typical normality. Any aberration from the typical in the formation of the teeth, and any departure from the normal in the position of the teeth, must proportionately destroy the balance between the several factors which, when present and working in unison, will afford ample protection to even this vulnerable locality.

Contact Points in Normal Arrangement.—Glancing again at Fig. 98, the student is asked to note that the teeth being in normal arrangement, the contacts are at the minimum, while yet being sufficient to afford protection. Since caries starts at these points of contact, it must be manifest that any malposition of the teeth which will bring into contact a greater area than normally should be in contact, not only increases the actual area of the vulnerable region, but by altering the protective form of the contact points, must necessarily add also to the vulnerability. In Fig. 98 note also that as each tooth is in its normal pose the greater portion of its exposed surface is brought into symmetrical alignment with its neighbors, so that any cleansing agency sweeping around the arch would come into touch with and consequently would cleanse the greatest width of such surface. Thus, where teeth are normally placed, a brush passing around the arch would cleanse nearly all the labial and buccal enamel, while a brush passed vertically over these surfaces would cleanse them entirely. An examination of the lingual surfaces (Fig. 99) discloses the fact that the truly normal arrangment again brings beneath the influence of a cleansing agent the widest expanse of surface.

It is equally evident that any malposition of even a single tooth must interfere with this cleansing effort. If a tooth be turned upon its axis, then a smaller part of its labial or buccal surface can be swept by the brush when the brush is used upon that part, and the same would be true when brushing the lingual surfaces. If a tooth extends beyond its neighbors, either buccally or lingually, not only will it become more difficult to cleanse that particular tooth, but its position must interfere more or less with the cleansing of its neighbors.

It is seen then that any aberration from the normal in the interrelation of the teeth renders them more difficult to keep clean, but it must be understood that aside from the artificial cleansing which is to be accomplished with brushes, powders, etc., the typical forms and arrangement of the teeth are such that the normal use of these organs leaves them moderately clean, so that the teeth in ideal normal occlusion are said to be "self-cleansing," this cleansing being accomplished by the lips, the tongue, and by the food passing over the surfaces of the teeth.

Fig. 99.—Occlusion of the molar and bicuspid teeth, internal view. (From photograph of a specimen in possession of Dr. F. A. Peeso.)

Terms Defined.—*Occlusion:* The relation between the upper and lower teeth when the jaws are closed.

Arch: A term used to designate the upper or lower teeth collectively.

Inclined Plane: The sloping surface of a cusp.

Mesial, Distal: Position is considered in relation to the median line or center of the dental arches. Hence, "mesial" means toward or nearest to the median line, and "distal" means away from or farthest from the median line.

Model: A reproduction of the dental arch or arches made in plaster of Paris.

Labial: Toward the lips.

Buccal: Toward the cheek.

Lingual: Toward the tongue. This term is used to describe the upper as well as the lower teeth.

Protruding: The tipping of the axis of a tooth so that the crown projects labially to normal.

Retruding: The tipping of the axis of a tooth so that the crown slants lingually to normal.

A STUDY OF NORMAL OCCLUSION.

Before the student can comprehend any description of malocclusion he must acquire a knowledge of normal occlusion. He should be able mentally to visualize a set of teeth in normal occlusion, as a standard picture with which to compare any set of teeth under examination, in order instantly to detect deviations from the normal.

Definition.—Normal occlusion is the normal relation of the occlusal inclined planes of the teeth when the jaws are closed (Angle).

As occlusion means the relation between the upper and lower teeth when the jaws are closed, it follows that normal occlusion means that all the teeth in both arches are so situated that they may best perform their functions, and that their interrelation shall be typical and therefore normal.

In a set of teeth in normal occlusion the teeth themselves are arranged in symmetrical parabolic curves, commonly called arches. This means that if a line be drawn across either arch, so as to touch the distal surfaces of the last molars, and a second line be drawn at right angles thereto and through the median space, or between the central incisors, then any two similar teeth on opposite sides of the arch (as for example the first bicuspids) will be equidistant from this central line.

Perhaps the next most noteworthy fact is that the upper arch is slightly larger than the lower, and that the outer cutting edges and cusps of the upper teeth droop over and consequently hide in part the similar portions of the lower teeth when the jaws are closed (Fig. 98). This latter condition is called the "overbite."

In a full denture there are thirty-two teeth. In the illustration which depicts one-half of an upper and lower jaw we should see sixteen teeth; but, as a matter of fact, the artist in endeavoring to expose the full surface of the upper central incisor has so turned the subject that in the lower arch we see an extra tooth, the lower central incisor of the opposite side. Mentally eliminating this extra tooth, by studying the illustration we observe that the smallest incisor is the central incisor in the lower arch, while the smallest molar is the last or third molar in the upper arch. It is in accordance with Nature's wonderful design, which aims to produce the highest efficiency in the use of the teeth collectively as a masticating apparatus, that this is true, for by this means every other tooth except these four occludes with two others. Again glancing at the illustration we see that the lower lateral incisor is in contact with the upper central and lateral; the upper central touches the lower central and lateral; the upper lateral antagonizes the lower lateral and cuspid, and so on around the arch, each tooth of either upper or lower jaw occluding with two teeth in the opposing jaw. The most important usefulness of this arrangement is seen when we consider those teeth which have cusps. For example, observe the first upper bicuspid, occluding with the cuspid and bicuspid of the lower arch. Any food caught in this locality is triturated between three powerful cusps, a much more effective plan than were each tooth to strike only one antagonist, as sometimes occurs where malocclusion is present.

This at once brings us to one diagnostic point. It being a fact that in normal occlusion all the teeth except the lower central incisors and upper third molars occlude so that each tooth antagonizes two, we note that the only place in the entire denture where the interproximal spaces coincide is at the median line. Two facts then may be remembered. Whenever any interproximal spaces above and below coincide (except these at the median line), malocclusion exists. Conversely, whenever the spaces at the median line do not coincide, malocclusion is present.

We should next consider those teeth which are supplied with cusps, viz., the cuspids, the bicuspids and the molars. In regard to the cuspids and bicuspids, when in normal occlusion the crest or extreme angle of the cusp should be exactly in line with the interproximal space between the two teeth with which it occludes. Or to phrase it differently, a line drawn through the central axis of a cuspid or bicuspid should pass between the two antagonizing teeth.

In all the teeth which have cusps, including the molars, each cusp has four slanting surfaces called inclined planes; note that of these the mesial inclined planes of the cusps of the upper teeth occlude with the distal inclined planes of the cusps of the lower teeth; and of course the distal inclined planes of the upper cusps touch the mesial inclined planes of the lower teeth.

As will be seen presently, however, a point of extreme significance, because used so often as a basis of diagnosis, is the occlusal relation of the upper and lower first molars. The student therefore should become thoroughly familiar with this cusp relation (Fig. 98). The upper molar has two buccal cusps, known as the mesiobuccal cusp and the distobuccal cusp. In normal occlusion the mesiobuccal cusp of the upper first molar occludes between the mesiobuccal and buccal cusps of the lower first molar, in such a manner that the crest or extreme point of the cusp coincides with a groove in the buccal surface of the lower tooth, known as the buccal groove. It is well also to observe that the mesiobuccal cusp of the lower molar occludes in part with the similar cusp of the upper molar and in part with the upper second bicuspid; also that the extreme mesial surface of the lower molar is on a line with the central axis of the upper second bicuspid. Attention is called to this fact here, as it will be again elsewhere, because while in the normal relation the lower first molar is slightly mesial of the upper first molar, it should not be farther forward than the median axis of the upper second bicuspid.

A study of the same set of teeth from the lingual aspect (Fig. 99), shows similar interlocking of the teeth and the general appearance is the same except that here it is the cusps and incisal ends of the upper teeth that are slightly hidden in consequence of the overbite, the converse of what is true of the buccal view (Fig. 98).

Summary.—1. Where teeth are in normal occlusion they are arranged in symmetrical parabolic curves and any two similar teeth on opposite sides of an arch will be equidistant from the central line, or axis.

2. The upper arch is larger than the lower and the cusps of the upper teeth droop over the lower. This is denominated the overbite.

3. With the exception of the two lower central incisors and the two upper third molars, each tooth in each arch antagonizes with two teeth of the opposite arch when in occlusion.

4. The interproximal space at the median line above and below should coincide. When they do not, or when any other interproximal spaces do coincide, a malrelation of the arches is present.

5. A line drawn vertically through the median axis of any cuspid or bicuspid should pass between the antagonizing teeth.

6. The mesial inclined plane of any cusp occludes against the distal inclined plane of the opposing cusp; the converse therefore is likewise true.

7. In normal occlusion the mesiobuccal cusp of the upper first molar occludes between the mesiobuccal and buccal cusps of the lower first molar.

MALOCCLUSION

Definition.—Any deviation of the teeth or arches from normal relation is termed malocclusion.

Malocclusion of Individual Teeth.—A tooth may occupy any one of seven malpositions, and it is even possible for it to be malposed in four ways.

These malpositions have been named as follows (Angle): (1) Labial or buccal occlusion. (2) Lingual occlusion. (3) Mesial occlusion. (4) Distal occlusion. (5) Supra-occlusion. (6) Infra-occlusion. (7) Torso-occlusion.

1. Labial or buccal occlusion means that a tooth crown is so malposed that it is labial or buccal of its true normal position.

2. Lingual occlusion means that a tooth crown is so malposed that it is lingual of its true normal position.

3. Mesial occlusion means that a tooth crown is mesial of the position which it should normally occupy.

4. Distal occlusion means that a tooth crown is distal of the position which it should normally occupy.

5. Supra-occlusion means that a tooth has erupted to an abnormal height in its socket.

6. Infra-occlusion means that a tooth has not erupted to a normal height in its socket.

7. Torso-occlusion means that a tooth is turned in its socket so that it does not occupy its normal place in the arch alignment.

In explanation of the statement that a single tooth may be in four positions of malocclusion at one and the same time, I would cite the following example: A molar tooth may be in torso-occlusion; in buccal or lingual occlusion; in mesial or distal occlusion; in supra- or infra-occlusion.

Classification of Malocclusion.—It is manifest, therefore, that there are endless varieties of malocclusion when viewed in the light of single or multiple malpositions of the individual teeth. It remained for Angle, however, to discover the possibility of formulating a classification for malocclusion, independent of these individual malpositions but based upon the relations of the two arches considered as units. Other writers have endeavored to erect classifications which do depend upon the individual malpositions, but in none of these is the line of demarcation between the described classes so well drawn that it may serve as an absolute division between the multiplicity of conditions that arise. The result is that often cases are found which might fall into either of two such classes or even into both. For example, we have had classes for "outstanding cuspids"—cases where the cuspids have erupted labially of normal. Again, classes of "open bite," meaning an infra-occlusion or lack of antagonization of the incisors. What are we to do then with a case where we have "outstanding cuspids" complicated with "open bite?" In the Angle classification no such confusion can occur. His lines of demarcation are so distinct, that there can be no lapping of boundaries.

Of his classification Angle writes:[1] "These classes are based on the mesiodistal relations of the teeth, dental arches, and jaws, which depend primarily upon the positions mesiodistally assumed by the first permanent molars on their erupting and locking. Hence, in diagnosing cases of malocclusion we must consider first, the mesiodistal relations of the jaws and dental arches, as indicated by the relation of the lower first molars with the upper first molars, the keys to occlusion; and second, the position of the individual teeth, carefully noting their relations with the line of occlusion."

Angle then has divided all malocclusion into three great classes dependent upon the mesiodistal relations of the arches considered as units. It is evident, then, that to make a diagnosis, we must always begin with a picture of normal molar occlusion in the mind, and with the question, "Is the mesiodistal relation of the molars normal on both sides?" The answer to this mental question will invariably classify the case.

[1] Angle, Seventh edition, p. 35.

To have such a mental picture we must carefully study normal molar relations, as shown in Fig. 98, noting that the mesiobuccal cusp of the upper first molar occludes with the lower first molar in such a way that a line drawn through the apex of this cusp will fall directly into the buccal groove of the lower molar. Or to phrase it differently, the mesiobuccal cusp of the upper first molar occludes between the mesiobuccal and buccal cusps of the lower first molar, whereas the mesiobuccal cusp of the lower first molar occludes between the mesiobuccal cusp of the upper molar and the buccal cusp of the upper second bicuspid. Thus we see that the mesial surface of the lower first molar is normally slightly mesial to the corresponding surface of the upper first molar. Hence, in studying mesial occlusion of the lower first molar, it is important to recognize the limitations of the normal mesial position of this surface in relation with that of its antagonists. When the cusps are not mutilated by caries or bad fillings, however, we may confine ourselves to an examination of the cusp relations.

The Angle Classification.—In studying a case, if we find that the mesiodistal relations of the upper and lower first molars on both sides are *normal,* the malocclusion belongs in Class I.

If the *lower first molar* on one or both sides is found to be *distal* to normal in relation with the upper first molar, it is said to be in distal occlusion, and the malocclusion falls into Class II.

If the *lower first molar* on one or both sides is found to be *mesial* to normal in relation with the upper first molar, it is said to be in mesial occlusion, and the malocclusion falls into Class III.

The distinctions, therefore, between Classes I, II, and III are very definite and should be readily comprehended. Some confusion has been caused in the minds of beginners by the fact that there are divisions and subdivisions, but these likewise may be so plainly described that there should be no difficulty whatever. Once having learned to distinguish between Classes I, II, and III, we next learn that there are no divisions in Class I nor in Class III. But Class II is separated into two divisions: Division 1, wherein the upper incisors *protrude,* and Division 2, wherein the upper incisors *retrude.* These are the sole factors by which the divisions of Class II are determined, and there remains no more to learn except the subdivisions. A subdivision is any case of malocclusion where the mesiodistal relations of the upper and lower first molars is *normal on one side and abnormal on the other.* If the abnormality be a distal occlusion, the case must be a subdivision of Class II, because all cases of distal occlusion are in Class II. If the abnormality be a mesial occlusion the malocclusion must belong to Class III because all mesial occlusions are in Class III.

The following recapitulation of the classification is copied from Angle, omitting his references to etiological factors with which we are not at the moment interested:

Class I. Arches in normal mesiodistal relation.
Class II. Lower arch distal to normal in its relation to the upper arch.
Division 1. Bilaterally distal, protruding upper incisors.
Subdivision. Unilaterally distal, protruding upper incisors.
Division 2. Bilaterally distal, retruding upper incisors.
Subdivision. Unilaterally distal, retruding upper incisors.
Class III. Lower arch mesial to normal in its relation to the upper arch.
Subdivision. Unilaterally mesial.

To fix the differentiations of this classification more firmly in the mind let us examine the illustrations of a few typical cases. In Fig. 100, an examination of the first molars discloses that on each side the mesiodistal occlusal relations are normal. On each side the mesiobuccal cusp of the upper first molar occludes between the cusps of

FIG. 100.—Models of a case of malocclusion, Class I.

the lower first molar, and a line drawn through the central axis of the mesiobuccal cusp of the upper molar, strikes the buccal grove of the lower first molar. This, then, discloses a bilateral normal mesiodistal occlusion of the arches, and the malocclusion consequently falls into Class I. For this illustration a case where the upper incisors protrude has been selected, that by comparison the student may better grasp the difference in the significance of protruding incisors in Class I and Class II, Division 1.

In Fig. 100, the normal mesiodistal relations of the first molars definitely fixes the case in Class I. Hence the protrusion of the upper incisors *has no significance* in connection with the classification of the case.

In Fig. 101, an examination of the molars shows that the lower molar on each side is in distal occlusion. The mesiobuccal cusp of the upper first molar does not coincide with the buccal groove of the lower first molar, but on the contrary falls between the mesiobuccal cusp of the lower molar and the buccal cusp of the second bicuspid. The case therefore falls into Class II, and *since the upper incisors protrude,* it must be in the *first division* of that class. Being *bilaterally distal with the upper incisors protruding,* it belongs to Class II, Division 1.

FIG. 101.—Malocclusion: Class II, Division 1.

In Fig. 102, we see a case quite like the last, and superficially like Fig. 100, but a study of the molars shows a *distal occlusion on one side* and *normal mesiodistal relations on the other.* And as the *upper incisors protrude,* it is placed in Class II, Division 1, Subdivision.

It is in Class II, because there is a distal occlusion; it is in Division 1, because the upper incisors protrude. It is a Subdivision because the distal occlusion is confined to one side. It is therefore unilaterally distal with protruding upper incisors.

FIG. 102.—Malocclusion: Class II, Division 1, Subdivision.

In Fig. 103, we find both lower first molars in distal occlusion. The case therefore belongs to Class II, which includes all distal occlusions. We note that the *upper central incisors retrude,* for which reason the case belongs to Division 2. It is therefore a case belonging to Class II, Division 2, because it is bilaterally distal with upper incisors retruding.

In Fig. 104, we see a case strikingly like the last, except that on close examination we find that the distal occlusion is confined to one side, for which reason it must be a subdivision case. It belongs, therefore, to Class II, Division 2, Subdivision, being unilaterally distal with retruding upper incisors.

Fig. 103.—Malocclusion: Class II, Division 2.

In Fig. 105, we find the lower first molars mesial to normal. Indeed, they are so far mesial that they have lost all occlusal contact with the upper first molars, so that the classification is very simple. The case must belong to Class III, which includes all mesial occlusions. An extreme case has been selected for this illustration, but the actual normal mesiodistal relations must always be in the mind as a mental picture

Fig. 104.—Malocclusion: Class II, Division 2, Subdivision.

with which the case in hand may be compared, and in the presence of the full complement of permanent teeth, if the lower molar is found to be mesial to normal, the case belongs to Class III.

Observe, however, the qualification "in the presence of the full complement of the permanent teeth." The premature loss of a temporary molar, or the extraction of a bicuspid may permit a lower first molar to drift abnormally forward, presenting a confusing picture. It is always to be remembered, therefore, that this entire classification is dependent upon the presence, or space for the eruption of, all the permanent teeth, and the drifting of teeth due to extractions or loss of temporary teeth is always a matter for separate consideration.

Fig. 105.—Malocclusion: Class III.

In Fig. 106, we find a mesial occlusion on one side, and a normal mesiodistal relation on the other, for which reason the case belongs to Class III, subdivision.

So much then for the classification or diagnosis of cases in which the first permanent molars are present. It is more than likely, however, that many cases will be seen before these molars are erupted or

Fig. 106.—Malocclusion: Class III, Subdivision.

after they have been badly mutilated or even lost through the ravages of decay. For this reason it is well to note that the occlusion of the second deciduous molars closely simulates that of the first permanent molars and consequently these teeth may be used as guides for classification. It has also been mentioned that the permanent cuspids are quite staple landmarks and are useful as guides to the occlusal conditions. At times the bicuspids may be all the individual has to offer from which to classify an abnormality. Hence the student can clearly see that an intimate knowledge of the normal relation of every tooth is absolutely necessary if an intelligent grasp of the abnormal is to be expected.

Etiology of Malocclusion.—One might write at great length upon the etiology of malocclusion without at all exhausting the subject. In this particular work it does not seem essential to discuss all the theories of all the theorists. The aim will be rather to disclose those facts, the knowledge of which will enable the hygienist to fulfill her avowed purpose of calling attention to, and so far as possible abating, those acts or causes which might bring about or aggravate malocclusion.

The factors involved as causative agents of malocclusion may be divided into the proved and the unproved. As examples of the unproved theories in relation to the causes of malocclusion, enlargement of the tonsils, nasal obstruction, mouth-breathing, and adenoids may be mentioned. Whether these maladies do or do not contribute toward malocclusion, they are evidences of a reduced vitality, and as diseased conditions, should promptly be corrected.

We are told that mouth-breathing causes malocclusions, and that adenoids cause mouth-breathing. Conversely, however, certain good rhinologists hold that mouth-breathing induces adenoids, due to the fact that the inhaled air, normally passing through the nares produces a tonic effect upon the upper pharynx, whereas when taken through the mouth and thus more directly into the lungs, the area usually occupied by the adenoid vegetations misses this tonicity supplied by the air, and the hypertrophies are induced. An ordinary rhinitis, or head cold, especially during early infancy, by occluding the nasal air passages, forces the child to breath through the mouth. If the rhinitis be long neglected, the mouth-breathing, which begins as a temporary necessity, may become a permanent habit. The theory at least sounds plausible enough. Consequently a hygienist who notices any negligence of this character, where her charges may be suffering with a head cold of long standing, should at once warn the parent or guardians of the possible ill-results. Far better would it be for the child to lose a few days' schooling while being kept in bed to cure a cold, than that the habit of mouth-breathing should become fixed.

Among the proved causes of malocclusion we may enumerate:

(*a*) The premature loss of deciduous teeth.

(*b*) Extraction of permanent teeth.

(*c*) Pernicious habits, and

(*d*) Lack of use.

There are other known causes which may be found in text-books, but those mentioned are of special interest to the hygienist.

(*a*) *The Premature Loss of Deciduous Teeth.*—The loss or extraction of a deciduous tooth, especially of the cuspids or any one of the buccal teeth, will almost inevitably produce a pernicious effect upon the permanent teeth. The space made by the loss of the temporary tooth almost invariably closes, in part or entirely, so that the opening needed for the oncoming teeth in that locality is reduced in proportion.

Why the Space Closes.—In the examination of a three-year-old arch, one wonders where the three large permanent molars will find space for eruption. This space, of course, must be provided by a growth of the maxilla and mandible distal to the deciduous teeth, distal therefore to the last deciduous molar. This growth is coincident with (if not actually caused by) the development and eruption of the permanent molars. The result is a forward or horizontal movement of the whole temporary arch. Let us study it in detail. To make room for the arriving first permanent molar, the temporary second molar must move forward. To accomodate this movement the first temporary molar must move forward, and so on around the arch, each tooth giving way as the tooth behind it advances. Let us suppose, however, that one of the temporary molars has been lost. A space is thus produced so that the first permanent molar may erupt without influencing the forward movement of any of the teeth anterior to the tooth extracted. Indeed, through lip pressure the space may even allow the anterior teeth to be forced backward. In this way, by closing of the space while the underlying bicuspid is yet deep in the bone, the bicuspid may be completely shut out of the arch, so that it either remains impacted, or else must erupt buccally or lingually of normal.

(*b*) *Extraction of Permanent Teeth.*—The loss of any permanent tooth breaks up the continuity of the arch and destroys the occlusion. It directly effects no less than five teeth. The two adjacent teeth losing the support of the extracted member, are often forced to drift or tip toward one another. This tipping and drifting is more likely to be extensive when the extraction occurs prior to the eruption of the second molars, as the eruption of these distal teeth induces a disarrangement of the teeth distal to such spaces. This tipping of the teeth interferes with the normal cusp interdigitation of these two teeth with the three antagonists of the opposite jaw. Thus, as has been said, the loss of one permanent tooth may directly spoil the occlusion of five others. Hence, of course, all permanent teeth which can be kept in a state of health, should be preserved when in normal position, and when out of position should be brought to normal occlusion, if possible.

(*c*) *Pernicious Habits.*—In regard to habits, perhaps the most common is sucking the thumb. This phrase, "sucking the thumb," is met throughout the entire literature, and is particularly supposed to induce protrusion of the upper anterior teeth. But the thumb is not always in the mouth in such a way as to produce this effect, nor is it always the thumb which the child introduces into the mouth. Recently a casual glance into the mouth of a baby girl patient of four, disclosed what seemed to be a protrusion of the upper incisors. The mother was asked, "Does this child suck her thumb?" Like a flash the child replied, "No, I suck two fingers; want to see me?" and she proceeded to give a demonstration. She placed just two fingers of her right hand in her mouth, the finger-tips curled downward under her tongue. In this manner it would seem that the weight of her arm had held the mandible downward and backward, so that a marked example of Class II, Division 1, had been produced, although none of the temporary teeth had yet been shed. The apparent protrusion of the upper teeth was no real protrusion at all. As the child was not a sufferer from adenoids, had no nasal obstruction of any sort, had never been a mouth-breather, and was the picture of health, it is reasonable to attribute the deformity of the jaws in her case to this peculiar method of sucking the fingers. The thumb is also sometimes introduced into the mouth in the same manner, and not always with the ball of the thumb against the upper teeth.

Other baneful habits are sucking the lips or the tongue, or habitually resting the tongue between the incisors, not forgetting the abominable practice of nursemaids, and some mothers, of giving the baby a "pacifier" or "comforter."

These habits are particularly mentioned here because it seems probable that in the near future the sphere of the dental hygienist will be so broadened that she will enter the homes of many children long before they arrive at the school age, in which case an important part of her duty would be to look for, and warn mothers against, these habits.

(d) Lack of Use.—This brings us to a consideration of a lack of use. It is a commonly accepted physiological law that the use of any organ, or part of the body, contributes toward its development. Normal use results in normal development, where not hindered by other agencies. Abnormal or immoderate use may cause an overgrowth, as we see in the muscles of athletes; while disuse results in underdevelopment or even atrophy.

The Growth of the Jaws.—If we examine the normal child denture at the age of three or four, we observe twenty teeth symmetrically arranged about the arches and completely filling them. When we remember that these twenty deciduous teeth will be succeeded by twenty permanent teeth considerably larger in size, we recognize that if the latter are to erupt in normal occlusion, the bones of the arches must become enlarged, or in other words, there must be a growth increasing the circumference of the arches. Since the growth of the temporary teeth themselves is already complete, a growth of their bony supports must result in producing spaces between these teeth. We see this beautifully shown in Fig. 107, which illustrates the upper and lower arches of a boy of four and a half years of age. We have but to glance at such a set of deciduous teeth to see how admirably Nature, when unhindered, will provide for all emergencies. We easily comprehend that, by growth, space is being provided against the advent of a set of larger teeth.

But what shall we think of such a set of teeth as is shown in Fig. 108? This child was five years of age, six months the senior of the other child, yet we find no spaces between the teeth and consequently no growth of the alveolar bone. We must wonder then, "Where will the permanent teeth erupt?" They certainly cannot appear in proper

Fig. 107.—Normal growth of dental arches. Age 4½ years.

alignment with such a lack of space. These two models then, illustrate well the contrast in appearance of a normally developing deciduous denture with one that is failing to take on proper growth.

It is but natural to believe that this development of the bones about the deciduous teeth is largely dependent upon the extent and nature of the use or disuse of the teeth.

The normal use of the teeth would necessitate the thorough mastication of food; food thus masticated would be properly insalivated,

Fig. 108.—Undeveloped dental arches. Age 5 years.

and hence properly prepared for its reception by the stomach. With all the organs of digestion in a state of health, the result would be the thorough assimilation of the food, a correct metabolism, and hence a proper share of the nourishment would finally reach the jaw-bones, so that the thoroughness of the work done by the dental organs would bring its own repayment in the normal share of pabulum brought to the alveolar environments of the teeth. In this manner a normal physiological cycle would be established, and of course any disuse of the teeth would proportionately cause a disarrangement of this cycle.

While it is well to bear these facts in mind, yet there is another aspect of use and disuse of the dental organs to which attention must here be called. Entirely aside from any interference with the proper nourishing of the body and of the jaw-bones, the use or disuse of the teeth directly affects the growth and development of the maxilla and mandible, through the muscular and mechanical forces of mastication. Indeed it is claimed that not only the bones of the jaws, but the entire cranium may be thus affected. To emphasize this fact, a liberal quotation is made from an article by Dr. Lawrence W. Baker, published in *Items of Interest*, February, 1911.

"Among the first voluntary coördinate muscular actions of a human being after coming into the world is that made with the muscles of mastication in taking food to sustain life. Long before the infant can hold up its head, or has gained control over those useful organs, the hands, the muscles of mastication are highly developed and are used with great vigor.

"During the act of nursing, the action of this set of muscles is so vigorous that it demands an increased blood supply, to the extent that the heart's action is greatly increased; the excessive flow of blood to these parts is indicated by a reddening of the whole head, and the fontanelles themselves are caused to pulsate so that the untrained observers comment on their movement.

"Later, with the advent of the dental equipment, this group of muscles is given more leverage, and its action becomes consequently more powerful; in fact, the force exerted on the bones of the head from the pull of these muscles during life is tremendous and amounts to many hundreds of thousands of tons of force. I have long been convinced that this great force on the skull, and the great flow of arterial blood to the head caused by this muscular activity, is a powerful influence in the development of the bones of the head and the important organs incased therein.

"It occurred to me that if the hypothesis regarding the influence of the dental equipment on the formation of the bones of the head were correct, interference with the laws of occlusion in the lower animals would show consequent effect in the formation of the bones of the skull; and if variation occurred it might throw some light on the most complex problem of the development of the human head.

"To test the theory the following experiment was performed: A litter of four rabbits was selected at the age of weaning. Two of the animals were operated on by grinding down all the teeth on the right side of the lower jaw and the superior right central incisor. As the teeth elongated, repeated grinding rendered them useless, so that all the mastication was performed on the left side. The fourth rabbit was kept in the normal state for a standard of comparison.

"After seven months, the skeleton of one of the rabbits was procured and the skull was found to vary as is shown in Fig. 109, which is a photograph of its upper aspect. It will be noted by the drawn lines that there is a deviation of the bones to the left. (Right and left in this description refers to the right and left side of the animal). The suture between the parietal and frontal bones does not run strictly at right angles to the longitudinal axis of the skull; the right frontal bone projects farther forward than the left one. It will also be observed that the left zygomatic space is longer and more advanced than the right space. The most noticeable deviation is in the nasal bones, both bones being twisted to the left.

FIG. 109.—The upper aspect of the skull of a rabbit operated on. Observe the unequal development of each lateral half of the skull.

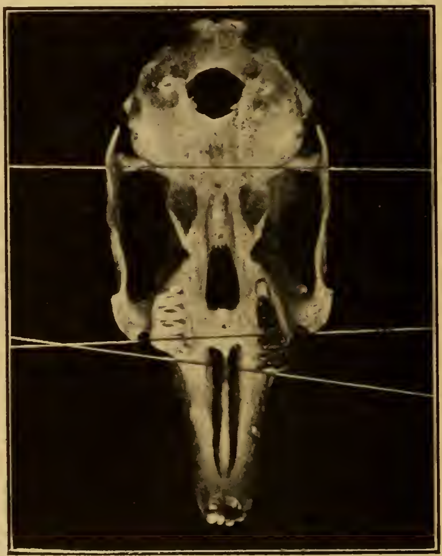

FIG. 110.—Lower aspect of Fig. 109.

"On the lower aspect of the skull, Fig. 110, it will be seen that the deviation extends throughout the entire skull. The most remarkable deviation is that the anterior root of the right zygomatic arch (the zygomatic process of the maxillary bone) is retreated while the body of the right maxillary bone itself with the teeth that it contained is greatly advanced.

"The results of this experiment seem remarkable to me.

"Who would have thought that by interfering with the laws of occlusion the skull would have decreased in weight, and that every suture and every bone in the head would have varied as we have seen? This experiment strongly indicates how important is the masticatory equipment of man to the development of the head, and it also brings fresh illustrations of the importance of the sadly neglected temporary dentition which serves during the important developmental period of childhood."

The previous quotation gives in full the details of Dr. Baker's experiment, and his findings in one case. His examination of the second rabbit upon which he experimented disclosed exactly similar variations from the normal, whereas the control animal was practically symmetrical.[1] Until future experimenters prove these deductions to be erroneous, we may agree with Dr. Baker that the disuse of the teeth may result in extreme interference with the development, not alone of the jaws, but of contiguous parts of the cranium.

Reasons for Lack of Use.—Disuse of the dental organs may be either involuntary or voluntary. It is involuntary when the habits of mastication are hasty, or where the food used is of such a character that

Fig. 111.—Caries of teeth causing voluntary disuse of the teeth.

heavy mastication is not necessary. What an injustice, then, is done to children who are fed upon gruels, sloppy food and other articles of diet which require little or no masticatory effort to reduce them to a consistency readily swallowed?

The voluntary disuse of the teeth is the direct result of caries which renders the chewing of food so difficult, or so painful, that the child elects either to swallow its food unchewed, or else to select food that needs no masticatory effort.

In Fig. 111, we see the right and left sides of the occluded models of a child four years of age. On the left side of the mouth caries has destroyed the little molars and cuspids almost to the gum line. We cannot look upon this picture without thinking of the rabbits, whose

[1] Dr. Baker has continued his experiments, and has had exactly similar results with animals other than rabbits. See his report thereon, Dental Items of Interest, July, 1916.

teeth Dr. Baker filed or ground away to prevent mastication on one side. When we recall the results of the experiment with the rabbits, we begin to appreciate the seriousness of such conditions in a human young one, during the most stressful periods of development. The word stressful is used because, whereas an adult needs only to restore the tissues of his body which are lost by use, a child must likewise do this and at the same time obtain and assimilate sufficient food with which to increase his weight and stature. How can he do this handicapped with a masticating apparatus so destroyed? In the experiment with the rabbit, Dr. Baker left the little animal one side of his masticating apparatus perfect, so that perhaps he might properly masticate sufficient food for the proper nourishment of his body. It is this fact that made Dr. Baker's results so significant. There is every reason to believe that the rabbits operated upon ate just as much food as the control animal, so that the divergencies from normal found in the skulls were not attributable to lack of nourishment, but to lack of use of one side of the jaws.

Fig. 112.—Same case as Fig. 111, occlusal view.

The child whose models are shown fared not so well as Dr. Baker's rabbits, because on both sides occlusion was extensively interfered with. The cavities in the teeth are so large that a considerable portion of their occlusal areas have been lost, and the approximal contacts likewise having been destroyed, the protection of the interproximal septa has disappeared, so that food readily packs upon these easily injured and sensitive tissues, with the result that mastication becomes painful, and the child voluntary declines to use his teeth.

Fig. 112, shows the occlusal view of these two jaws, and the extent to which caries has destroyed the occlusal contactual area is disclosed. Comparing these models with those shown in Fig. 107, we note the lack of development.

At this point it may be well to consider again the models shown in Fig. 108. These likewise show lack of development of the arches, yet the teeth themselves are not affected by caries, so the child could have used them perfectly; therefore it is not to be claimed that disuse is the sole cause of lack of development. It may be the chief cause in some instances and only one of several factors in others. In the case of the child whose models are shown in Fig. 108, the physical history is not known. It will suffice for present purposes to consider two possible hypotheses. While this child cannot have suffered from voluntary disuse of the dental organs, since the teeth are all sound, there may have been involuntary disuse due to the soft nature of his food.

FIG. 113.—Malocclusion due to lack of use.

Again, considering the perfectness of the teeth, this may not be a case of lack of development at all. There is no definite age at which a particular development of the jaws must occur. We cannot say certainly that the first permanent molars will erupt at a stated age, the incisors at another, the cuspids at another. The writer has seen a complete denture of thirty-two teeth at the age of fourteen, and in

FIG. 114.—Same case as Fig. 113, occlusal view.

another case, the upper cuspids arriving as late as the nineteenth year, in which case all the previously erupted teeth had likewise appeared long after what is supposed to be the normal time of eruption. Looking at a child denture prior to the eruption of the first permanent molars, if we note growth spaces, as seen in Fig. 107, we may say that normal development is present, but in the absence of such growth spaces, as in Fig. 108, we cannot positively decide. It may be a case of lack of development (as a mere illustration of which the models are used), or it may be a case of slow or tardy development.

As examples of a period slightly later than that shown in Figs. 111 and 112, Figs. 113 and 114 are introduced. This child's mouth was first examined prior to the appearance of the permanent molars. Not a tooth in the two arches was free from caries. The upper incisors were barely showing above the gum line, and all four were abscessed, for which reason they were extracted, as were three or four others. Complete lack of occlusion existed. The child was undersized, anemic, and of a generally degenerate appearance. Her father was a physician, however, and after removal of the abscessed teeth he was advised to feed the child on food that would yield as much nourishment as possible. It was impossible to obtain models of her mouth; it would have been cruel to try. When next she was seen, two years later, the models here illustrated were made. Even with the eruption of the first molars, the masticating possibilities have not been greatly improved, as they decayed almost as fast as they appeared, so it was said. However that may be, we have here a marked case of prolonged lack of use and malnutrition and cannot be surprised at the resultant malocclusion. On one side we note that the lower molar is in distal occlusion. On the other side the occlusion of the molars is apparently normal, but there is little reason to doubt that the lower molar has drifted forward because of the premature loss of the two temporary teeth. In any event it is a marked example of malocclusion due to lack of use following the ravages of caries in the temporary set, so that from this case alone we may gain some cognizance of the possible evils of dental disease which might have been prevented to a great degree by proper attention to mouth hygiene.

CHAPTER X.

PYORRHEA ALVEOLARIS

By R. G. HUTCHINSON, Jr., D.D.S.

Strictly speaking, the term pyorrhea alveolaris can be applied only to conditions in which there is an exhibition of pus. As this is the case in but a percentage of the pathological processes which destroy the tissues supporting the teeth, it is a most inadequate and inappropriate term to use as descriptive of such conditions in general. Common usage often brings about the acceptance of terms or words improperly applied, and as the profession has almost universally employed the name pyorrhea alveolaris in speaking of infections affecting the peridental membrane and alveolar process, together with the overlying soft tissues, we are therefore justified in accepting such application.

As the general causes leading to infection, the ultimate results of such infection, and the treatment are substantially the same in all cases, they will be considered collectively.

Etiology.—Every mouth contains many different forms of bacteria, pathogenic and otherwise. The mouth, with its temperature, moisture, and abundance of culture medium, is an ideal incubator. Cultures are therefore easily established. Normally, the tissues offer sufficient resistance to prevent destruction, unless an extremely unsanitary condition is permitted to exist. As the establishment of a destructive infection must result from the overcoming of resistance by attack, attention must be directed to the cause of lowered resistance as well as the direct cause of infection.

Clinical observation has shown that in the great majority of cases the infection exists at some point of injury. In other words, trauma is frequently the starting-point of pyorrhea alveolaris. The tissues having been injured, inflammation results, the active organisms which are present establish a focus and the destruction begins.

There are some cases, however, in which there is no appreciable traumatic condition. Such cases are due to general low resistance to the particular form of organism which establishes itself.

The conclusion must therefore be that pyorrhea alveolaris is caused by an infection of tissue whose resistance has been reduced, either by traumatic influence, or on account of some systemic factor.

It must always be borne in mind that the presence of bacteria is necessary, and pyorrhea alveolaris cannot exist without them. When the tissues are uninjured and high resistance exists, no harm will be done by their presence, but when the attacking force is stronger than the defense, a pathological condition is the result.

Therefore the matter may be summed up in this way: The causes of pyorrhea alveolaris are positive, active or direct; and negative, passive or indirect. The former are local and the latter constitutional.

Even with a very high constitutional resistance, such resistance may be overcome by injury, and infection may occur. It is all a matter of the relative strength of attack and defense. Pyorrhea alveolaris is not, as has often been said, "A local expression of a systemic disorder." If a systemic disorder which affects nutrition or elimination exists, of course a local lesion is more easily established, and its progress will be more rapid and destructive.

Whatever strengthens the attack or weakens the defense, facilitates the establishment and progress of the local disease; and whatever weakens the attack or strengthens the defense, is unfavorable to the local pathological condition.

Causes.—The most common cause of pyorrhea alveolaris is malocclusion. The improper apposition of the occlusal surfaces results in a venous hyperemia of the peridental membrane, so lowering resistance. Also through malocclusion, the teeth are not performing normal function, and the tissues surrounding them suffer from malnutrition. When the teeth are crowded, the alveolar septum is thin and less resistant to attack, and it is always more difficult to maintain sanitation.

Some of the other local exciting causes are faulty dental operations, such as ill-fitting crowns and bridges which not only lacerate the tissues but accumulate food débris which the patient cannot remove; fillings impinging on the gum margins; fillings improperly contoured, allowing impaction of food in the interproximal space; septic teeth; improper application of rubber dam and clamps; rapid or excessive separation of teeth; laceration of tissues in finishing fillings; injury by improper instrumentation, for the removal of tartar, etc. In short, anything which establishes trauma, invites pyorrhea alveolaris.

As before stated, the systemic factors are passive or negative, and may be inherent or acquired. Some individuals possess to a high degree the ability to repair tissue which has been injured and to resist injury, or to resist many forms of infection, and others do not. This is an inherent factor.

Where such systemic diseases as tuberculosis, diabetes, Bright's disease or syphilis occur, pyorrhea alveolaris may be present in an aggravated form on account of low resistance, but almost invariably the inception of the pyorrhea antedates the establishment of the systemic disease.

Progress of Disease.—Pyorrhea alveolaris begins with an inflammation either at the point of injury or at the gingival margins, especially in the interproximal space. The inflammation results in the formation of deposits of serumal calculus, which becomes what may be called a secondary exciting cause. In some cases pus is formed, and in others destruction of the tissues takes place without pus being present. This destruction will continue until the teeth are lost, unless correct treatment is given.

Symptoms.—The symptoms vary according to the existing conditions and the stage of progress. In its inception, slight redness of the gingiva presents, sometimes with more or less serumal deposits. In more advanced stages, the gums will be highly congested, pus flowing profusely and teeth loosened.

There are many cases, the existence of which can be determined only by careful thorough exploration under the gum margins. Where much tissue has been lost, or deposits on the necks or roots of the teeth are present, there is no difficulty in determining the presence of a pathological condition.

Treatment.—The first step in the treatment of any case of pyorrhea alveolaris should be to determine where excessive stress exists in occluding the teeth, both at rest and in every possible position to be assumed by the jaw. All cusps must be properly ground and points of contact established in such a way that the stress will be equally distributed in all positions.

All faulty dental operations should be corrected.

Septic teeth must be sterilized or removed. The sooner this is done, the better the result of instrumentation will be.

It must be remembered that not only must health be restored, but function must be established, and finally, sanitation maintained. Any tooth which cannot be kept in a sanitary condition *by the patient*, should be removed. A sanitary artificial substitute is always preferable to an unsanitary natural organ.

All deposits of calculus must be removed and surfaces of roots delicately curetted for the removal of necrotic membrane, and finally, the teeth must be polished perfectly.

In treating pyorrhea alveolaris, every factor which tends to injure the tissues or cause infection must be considered and properly removed, or failure is inevitable.

The operator removes that which nature cannot overcome, but nature heals and builds up the tissues. Therefore nothing harmful must be left and nothing must be done to interfere with that reparative process which must take place in order to effect a cure.

Practically no systemic condition which does not prostrate a patient will prevent successful treatment, and most systemic factors can be ignored in the treatment, except that more delicacy and care must be exercised where general low resistance exists. Failure is often due to excessive injury attending unskilful instrumentation and is frequently followed by a secondary infection more serious than the original.

Postoperative Treatment.—After the disease has been eliminated and health restored, it must be maintained. This is accomplished mainly through sanitary measures, both by the patient and the operator. The intervals between prophylactic treatments must be determined in each individual case.

Prophylaxis means prevention of disease, therefore the cleaning of the teeth by the operator must be done before recurrent inflammation is established.

The fact that prophylactic treatment is necessary in order to maintain health in the oral cavity in no way proves that the disease is not cured, but on the contrary, proves the local origin of pyorrhea alveolaris. Even where systemic predisposing factors exist, pyorrhea alveolaris either primary or recurrent, can be prevented by local measures alone.

The point at which resistance is overcome varies in different cases.

Medication.—Medication, either local or constitutional, is practically useless as a curative factor. Foreign irritants and pathological tissue must be surgically removed, and causative factors eliminated. The only effective use of medicaments consists of the application of such materials as will tend to prevent recurrent infection and act as palliatives. Whatever is antagonistic to bacterial growth, without irritation or destruction of the tissues, is conducive to the establishment and maintenance of health. A healthy mouth can neither be established nor maintained, but by depriving the bacteria as perfectly as possible of culture medium, we lessen the number by a starvation process. The use of mild antiseptics inhibits bacterial growth in food deposits which the patient cannot remove, and reduces the virulence of the bacteria present.

Vaccine Treatment.—The use of vaccines is not only unnecessary but detrimental, as such treatment merely makes possible the continued existence of mechanical irritants, bacteria, and pathological tissue without the exhibition of superficial symptoms. Such masking of symptoms misleads the operator into believing that a cure has been effected when such is not the case. If the proper surgical treatment has been given, in every detail, and the patient faithfully carries out proper instructions, nature will rapidly repair the damaged tissues without any other assistance. This applies in a general way to powerful germicides and astringents applied locally. They give only temporary relief, and are liable to ultimately cause increased destruction of tissue.

The only logical method of treatment of accessible infections is to remove direct causes, and not to establish an artificial resistance which permits their maintenance.

Results of Pyorrhea Alveolaris.—Until recently little attention has been given by either the medical or dental profession to the appalling results often attending pyorrhea alveolaris. The dental profession has recognized the destructive effect locally, but not to the fullest extent. Such conditions as death of the dental pulp, necrosis of the bone, empyema of the antrum, and, in fact, every pathological condition common to the mouth often has as its starting-point, pyorrhea alveolaris.

What is even more common and serious, is the great variety of systemic effects of this disease. Pus, septic discharges, toxins, and the organisms themselves enter the system, both by ingestion and direct absorption, are carried to every part of the anatomy, and establish pathological conditions which are often fatal.

Such eminent medical authorities as Drs. Osler, Hunter, Mayo and others, regard mouth infections as the frequent source of such systemic diseases as all forms of digestive disturbance including appendicitis, nephritis, endocarditis, colitis, rheumatic fever, arthritis deformans, septicemia, anemia, general toxemia, tonsilitis and pharyngitis, gastric ulcer, abscess of glands and other tissues, such as carbuncles, and all conditions having, as their origin, infection.

Even the common communicable diseases are fostered by infected mouths. Statistics show a remarkable decrease of such diseases in institutions where oral sanitation is practised.

Prognosis.—When correct treatment of pyorrhea alveolaris has been conducted, and proper prophylactic measures carried out subsequently, there is practically no such thing as recurrence. When there is a continuance or recurrence, it is almost invariably due either to lack of knowledge or skill on the part of the operator, or failure on the part of the patient to carry out instructions; presuming, of course, that proper instructions have been given.

CHAPTER XI.

ODONTALGIA AND ALVEOLAR ABSCESS.

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ODONTALGIA.

There is nothing that has a greater horror for the world at large than toothache. To the layman, every kind of pain in the dental region is summarized in that word. The variations in the nature and characteristics of such pains have a most important diagnostic value. While it is true that the tales of woe that the patient sometimes relates are very trying to the listener, nevertheless it behooves the dental hygienists to pay the most careful attention to the details of such conditions, if they expect to make a correct report on conditions that they find.

The sensation of pain is transmitted by the nervous system. The nerves, as they ramify through the human body, can readily be compared to a complicated telegraph line. The same pair of nerves that supply the dental regions go to the eyes, nose and ears. An irritation of a nerve terminal, frequently is not felt at the point of irritation, but at some other place, which may be the most remote point of the body. This is termed referred or reflexed pain. Following out our telegraphic simile, the shock goes direct to the brain, and is then transmitted to the terminal of some other line. Consequently, it is always well to bear in mind the possibility of almost all forms of pains having a dental origin.

The most common form of toothache is that produced by the inroads of dental caries. As the enamel is at the very first destroyed, there is very little sensation, because the inner layer of dentin endeavors by nutritional changes to protect itself. As caries approaches nearer the pulp, there comes a place where this protection ceases, and where the slightest thermal change causes intense pain. Heat, cold or acid formations all produce the same character of pain, and the source of this pain is very easily learned by observation. The entrance of the explorer in a cavity generally suffices to expose the cause, and the case becomes one for the dentist.

There is, however, another form of odontalgia which should be of more interest to the dental hygienist. Without entering into the theories of erosion, it is sufficient to say that under certain circumstances the enamel is dissolved. This is most likely to take place at the gingival margin on either buccal or lingual surface, and frequently is followed by the most exquisite sensitiveness. The patient will generally call attention to the pain produced when these surfaces are polished, in contrast to the feeling of intense satisfaction produced by proper manipulation of the orange-wood stick over an ordinary enamel surface. Careful observation will demonstrate the fact that the gingivæ, which for years have not been massaged or cleansed, generally covers these most sensitive areas.

Not uncommonly is it the case that the pain caused by such erosions has made the patient apply to the dentist. Often the distress will be so great that the patient is positive that the offending teeth must be lost. There is nothing that regular prophylactic care will serve better than the cure or alleviation of such distress. Consequently, the hygienist is able to give such cases a very favorable prognosis if the patient will carefully follow out the proper daily hygienic care of the mouth.

In such cases the terminal circulation has become impaired, and the result is an abnormality in the excretion of the mucous follicles. Débris of foodstuffs fermenting, leave an acid condition, and together with this, are found bacterial plaques.

All these combined factors produce the subsequent enamel deterioration. The proper use of the orange-wood sticks under the gingival margin of the gums will, in conjunction with frequent gum massage by the patient, tend to restore these tissues to a normal condition. Of course enamel that has been lost cannot be restored, but when the inroad of erosion has stopped, the solution of the enamel surface ceases, and after a while the dentin acquires a surface somewhat similar to enamel and the sensitiveness disappears.

There are other forms of pain that come under the head of neuralgias or tic douloureux. These vary greatly in their symptomatology. There may be a sudden sharp, piercing pain, or on the contrary, a pulsating throb. This pain may occur at regular or irregular intervals. Pressure on nerve fibers is generally regarded as the cause of such trouble. In exostosis of the roots of teeth we find a common cause. As the roots thicken in size they begin to occupy a space that had been tenanted by something else, and pressure on the peri-apical tissues is created; if the pressure is exerted against nerve fiber, one of the most severe forms of neuralgia is likely to ensue.

An abnormal supply of nutrition to the cementum is the cause of exostosis. The Roentgen rays make the diagnosis very easy, where formerly it was one of the most difficult of conditions to diagnose. In like manner the calcific deposits in the pulp are produced by extraordinary nutritional disturbances. These deposits vary greatly in size, shape and appearance. They may simulate minute seeds, nodules or pulp stones of more or less rounded shape, or they may be jagged and star-shaped. They may appear to coalesce and form one large mass of inorganic material, completely occluding the pulp chamber. It does not take much imagination to conclude that a star-shaped and jagged pulp nodule pressing on nerve fibrils will produce very great pain. Fortunately the roentgenogram here affords great diagnostic assistance.

There are two forms of toothache that have a very important bearing on the study of the symptomatology of alveolar abscess. The following is a typical history: The tooth is aching badly, especially when subjected to cold and heat. It becomes very sensitive to the touch. One morning, on awakening, the individual is very happy to find that all pain has ceased. Ice-water no longer produces this indescribable pain. The pulp in the tooth has lost its vitality. The sense of security on the part of the individual is not well placed. About a week later a sudden intense pain is experienced from heat that may reach the tooth. Cold now has a tendency to bring relief, but heat only produces a typical neuralgic effect. During this interval pyogenic bacteria have gained entrance to the pulp chamber, and infection of this organic tissue has begun. The tooth has now become exceedingly sensitive to the slightest touch. On opening the pulp chamber the pulp will be found more or less purulent, and the indescribable but well-known odor of dead pulp adds to the unpleasantness. An incipient alveolar abscess has already started in the peri-apical region. This is the acute stage of alveolar abscess.

The pain that is caused from a dying pulp is almost the antithesis of the pain produced by an incipient alveolar abscess. It is frequently difficult to demonstrate to laymen that the severest form of toothache can be present after the pulp is dead. It is, however, of supreme importance that this differentiation in the character of the pain, when the pulp is dying and that experienced where later infection of the pulp has taken place, should be thoroughly mastered by the dental hygienist.

The primary object of introducing odontalgia in this chapter is for the very purpose of impressing on the dental hygienist, the necessity of being able to differentiate between the various forms of odontalgia of which the patient will complain.

It is important that the initial symptoms of a dying pulp, as indicated by the character of the pain, should be thoroughly mastered, as such a case should have immediate dental service. Dental attention may be postponed in such cases, without any further detriment than the suffering of the patient. When, however, the pulp has once died, and the tenderness and sensitiveness to heat indicates the onset of infection in the pulp chamber, no delay of operative treatment is excusable. A difference of twenty-four hours in opening the pulp chamber of such a tooth may have a vital bearing on the ultimate preservation of the tooth. At this time the pulp chamber should be entered with extreme care, so that no infection is forced through a foramen. If the peri-apical region has not become infected, every care should be taken that this evil be avoided. The besetting sin of dental operations is undue haste where great care is required to avoid injurious consequences. Time plays such an important role in dental therapy that many good dentists have been known to yield to the temptation of hasty procedure.

The dental hygienist will frequently be found at the side of the dental chair acting in the capacity of a trained assistant to the dentist. Possessing a knowledge of the care requisite in the handling of such cases, her presence will unconsciously act as a brake on the desire of the dentist to go ahead at full speed without regard to consequences. Even when infection has once reached the peri-apical region, it is of the greatest importance that no treatment be employed that will tend to increase the area infected. In this respect too great caution cannot be urged in the use of any of the great number of proprietary preparations, which depend on setting free formaldehyde.

The writer has a keen recollection of a case to which he was called in consultation by a much-worried physician. The patient's temperature had risen to 105.5°. It was a case of acute alveolar abscess of an upper incisor. A large dressing of one of these proprietary nostrums had been placed in the root canal, which had a wide-open foramen. The great amount of formaldehyde passing through the foramen mechanically carried the infection up to the floor of the nose. Prompt surgical measures at this point, at least one-half inch above the end of the root, caused the temperature to drop to normal within twenty-four hours.

ALVEOLAR ABSCESS.

Between 1880 and 1890 the science of bacteriology began to have a marked influence both on the teaching and treatment of diseases of the body. Since that time the achievement of bacteriologists has produced an ever-changing transition in the point of view of mouth conditions. This change in the treatment of disease has been much more rapid in other parts of the body than in the mouth, and this is due to the fact that a large percentage of dentists are not medically trained men.

It is worthy of note in this respect that one of the earliest works of value was the production of a dentist, Dr. W. D. Miller, at that time of the University of Berlin, who published in 1890 his classical work on microörganisms of the mouth. The stimulus of this work in itself would have kept the scientific progress of dentistry on a par with that of the rest of medicine if the majority of dentists had been medically educated. The ever-widening gap between dentistry and medicine, since Miller's work was published, has been due to this unfortunate condition of affairs. It is impossible to separate one part of the body from another. Microörganisms that are found in the mouth may reach every part of the body. When disease becomes a serious matter it is found that the infecting microörganisms use the lymph channels and other media of circulation and by their own motile force they travel to any part of the body. Consequently, it is only a question of time when no one will be permitted to commence the practice of dentistry unless thoroughly educated in the study of health and disease.

It is on account of this absence of pathological knowledge, due to the lack of general medical education, that this subject is so inadequately understood by the majority of dental practitioners. The hygienist is to be educated to work in a field where the possibilities of infection caused by some of these microörganisms should be constantly borne in mind. It is important that the danger involved should be appreciated. Even if with the utmost care the hygienist does not help to produce infections, there must also be steadfastly in her mind the possibility of aggravating infected areas if the dentinal tissues are handled without a due appreciation of this danger.

Abscesses are infectious degenerations of tissue. They are the result of an infection produced by some form of pyogenic bacteria. These bacteria yield in turn various kinds of toxins, which become the real agents of tissue destruction. When the organism is of a hemolytic or blood-dissolving type of sufficient virility, it produces irritation, inflammation, and a resultant breaking down of the tissues into pus. Where, however, the bacteria have a very low power of virility, like the Streptococcus viridans, the tissues do not break down into pus, but nevertheless toxins are produced.

When it is considered that at all times the mouth is filled with living bacteria, the ever-present danger of the individual to infection cannot but be apparent to any observer. If it was not for what is spoken of as the immunity of the individual, human life on this planet would have long since ceased to exist; but there are certain forms of cells that act as a protecting army against these attacking forces. This defensive power is lodged, to a large degree, in the white blood corpuscles or leukocytes. The gum tissue itself, when unwounded, is a defensive agent. There are also certain elements in the blood itself, which help to maintain this condition known as immunity. While in this state the pathogenic bacteria have practically no effect against the defense which the individual possesses. There comes a period or periods in every human life when this defense becomes weakened, and then infection is likely to take place in some part of the body. When this period arrives, the area to become infected is that part of the body which offers the least resistance. This state is known as *locus minorus resistentiæ.* In other words, the place with the least resistance is the spot that the bacteria seek out when this defense becomes more or less weakened. If an individual has in his mouth one or more teeth which have been ineffectually treated, where imperfect pulp removal and imperfect root-canal filling has been done, this place will be at once invaded by the hostile bacteria as the point of least resistance, and is therefore likely to become the infected area.

Unfortunately, an inferior type of constructive dentistry plays a very important role in leaving places of this kind in the dental region.

The great demand in this country for dentistry at a moderate price has been one of the greatest causes of this unfortunate condition of affairs. A tooth in which pulp work has been done imperfectly, may retain a comparatively healthy condition as long as the individual retains this state of immunity. This condition is frequently destroyed by the intervention of some other infectious disease, as for example, a severe attack of influenza, which is very epidemic at certain times of the year in this country. The weakened condition of the individual, from an attack of this nature, at once impairs his immunity and the parts about this imperfect dental constructive work become the place of least resistance which the pyogenic bacteria attack. In the same manner, imperfect mastication and faulty assimilation of food, lack of attention to common-sense rules of hygiene, and numerous other factors of this nature, in fact age itself, tend to depreciate more or less at times this condition of immunity and thus to bring the individual into a state where infection becomes possible.

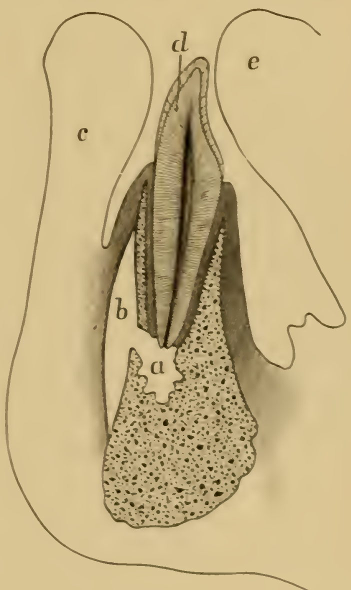

Fig. 115.—Acute alveolar abscess of a lower incisor in the third stage, with pus cavity between the bone and the periosteum: *a*, pus cavity in the bone; *b*, pus between the periosteum and bone; *c*, lip; *d*, tooth; *e*, tongue. (Black.)

For the sake of convenience, these abscesses may be considered in their principal forms, acute and chronic. The initial attack is generally spoken of as an acute alveolar abscess. It begins with a local generation of heat, rise in body temperature, constantly increasing inflammation, and edema of the localized infected area. Then pus forms, and if the abscess produced is not opened surgically, it seeks release from its environment by the path of least resistance. This is generally through the plate of the alveolus; sometimes, however, it follows the sheaths of the tissues and is evacuated at some remote point, which always makes the diagnosis of the locus of infection of such cases more difficult. Abscesses of this nature have often been known to discharge into the clavicular region, and much more frequently through the cheeks of individuals. (Fig. 115.) When the active symptoms of an attack of this kind have subsided, as they will after a time even without treatment, the abscess assumes a latent form and now is spoken of as a chronic alveolar abscess. It is not an uncommon thing for dentists to assure their patients that an abscess has been cured because its active symptoms have disappeared, when perhaps in a month or six months, or in a year or years, it may break out afresh, and thus show that it has not been cured. These outbursts of a chronic abscess are generally attended with none of the pain and discomfort which accompany the initial attack. They are often spoken of as harmless little gum boils, instead of being recognized as a very powerful factor in breaking down immunity. The extent of inflammation which takes place as a result of infection of this kind, is dependent upon the nature of the infecting organisms. These vary largely in their degree of virility. The more powerful microörganisms are of a hemolytic type, and produce the ordinary acute alveolar abscess. A much more dangerous organism, however, is non-hemolytic, generally one of the streptococci, which possesses so small an amount of virulence that it is frequently incapable of producing a degree of inflammation sufficient to cause an irritation that will be appreciable to the affected individual. As a result of this low degree of inflammation, nature builds up a defensive line of fibrous tissue around the infected area, which in a short time becomes a regular envelope entirely covering the abscess tract. The product is known as a granuloma or blind abscess, perhaps the most serious infective result that could be produced (Fig. 116).

Fig. 116.—Granulomata or blind abscesses.

In the dental region, a granuloma may become encased in the alveolar structure in the periapical space, where it may be unnoticed and dormant for years. However, it forces through this fibrous envelope into surrounding tissues, injurious toxins or products of its multiplication. These toxins are carried by the lymph channels to the various organs, where their energy gradually tends to undermine these organs and to produce grave chronic diseases, among which may be mentioned arthritis deformans. It is now well recognized that many instances of grave cardiac disease of an infectious type can be traced back to untreated alveolar abscesses.

Dental Pulp.—In considering this topic, a thorough understanding of dental histology is necessary. It is especially important to remember the division of this tissue into inorganic and organic. Inorganic material itself is not capable of becoming infected, but there is always strata of organic matter intermixed with the inorganic, which, becoming infected, help to break down the inorganic tissue. The pulp of the tooth in a normal condition is entirely of organic nature, and thus open to infection, as it affords an inexhaustible supply of nutriment for pyogenic bacteria. Perhaps the most important single feature of the pulp is its vascularity. As long as it retains a normal blood circulation, infection of this jelly-like mass is impossible.

There are various ways in which the normal circulation becomes impaired, and the pulp loses its vitality. Dental caries is perhaps the most common cause. The inflammation resulting from this disease invariably reacts on the pulp, manifesting itself in various ways. It may lead to fatty degeneration, or abnormal fungous hypertrophy, etc. Under the conditions of caries near the pulp, it readily becomes the prey of invading bacteria with resulting infection (Fig. 117).

Fig. 117.—Fatty degeneration of the pulp.

The irritation of the pulp, whether from caries or other causes, often produces an entirely different abnormal condition. Under certain conditions, there appears to be an effort of nature to protect the organ, and this results in an excessive supply of inorganic material which in turn results in a calcific degeneration of the pulp. This condition is usually found in adult life, becoming more marked as age advances. It is found in very varied circumstances. The pulp may be found impregnated with little seed-like bodies, crystalline in their formation. From just a few of these pulp nodules, the degeneration may progress until the entire pulp is found to be practically calcified with just a microscopic strata of organic structure permeating it (Fig. 118).

This calcification often has a tendency to strangulate the already impaired circulation, and thus produce death of the pulp. The proper removal of such a pulp is no mean surgical triumph, and will be referred to later.

Injudicious dental operations in the shape of large metallic fillings in close proximity to the pulp, are frequent sources of the irritation producing this degeneration and subsequent death of the pulp. Accidents are frequent causes of traumas resulting in a rupture of the bloodvessels entering the foramina and thereby causing the death of the pulp.

Fig. 118.—Pulp calcification.

The pulp having died, the tooth is left with this dead body in its interior, a prey to the first invading bacteria. Consequently, it is essential that the corpse be speedily removed. This means the removal of every particle of organic tissue under strictly aseptic precautions, and the hermetic sealing of the root canal. There is a type of these cases in which the pulp does not die, but as the calcification progresses to almost the point of obliteration, a severe inflammation of the end of the root and peridental tissues takes place. This inflammatory process is caused by the microscopic elements of organic tissue left in the pulp. The pericementitis is often very severe, and is accompanied by serous exudation around the necks of the teeth. Only the cleansing of such canals through every foramina will cure this condition. An inflammatory exudate from this source is only too frequently diagnosed as pyorrhea alveolaris, especially when the tooth shows signs of loosening. All the recognized treatments for pyorrhea only increase the inflammatory conditions, but when the organic matter has been completely removed so that a broach will pass through every foramen, the tooth will at once tighten in its socket and all exudate will cease.

The symptoms following infection depend largely on the nature of the infecting organism. When it is of the hemolytic variety, pus soon develops, and the extent of tissue invaded varies greatly. Cases of this type are frequently diagnosed and treated as pyorrhea alveolaris. To many medical men, as well as to many dentists, this is the only answer to the problem of pus in the mouth. Radiography has made the correct diagnosis of such conditions a comparatively easy matter.

It is inexcusable, at the present time, to treat a supposedly pyorrheal mouth without first studying the roentgenograms of such a mouth. An alveolar abscess with a fistulous opening at the gingival border, while very deceptive from the standpoint of physical examination, becomes easy of diagnosis in studying a properly focussed roentgenogram. The destruction of alveolar structure around the end of the root makes this diagnosis very simple. While a pseudo form of pyorrhea may develop from the pus discharging around the neck of a tooth, all methods of treating the pyorrheal condition must fail, unless the pulp of the tooth is properly removed and the diseased structure in the peri-apical region is completely eradicated (Fig. 119).

Fig. 119. — Roentgenogram showing alveolar abscess erroneously diagnosed as pyorrhea alveolaris.

In almost all cases of pulps dying from trauma, and frequently where the infecting microörganism attacks the foraminal entrance in the peri-apical region, the bacteria are of a non-hemolytic variety, and most generally when isolated are found to be the *Streptococcus viridans*. It is a well-noted clinical fact that this attenuated form of streptococcus is not uncommon in this region.

Wherever partial pulp removal is practised, and any method of medication of the remnant of the pulp tissue is employed, with the object of making the parts immune to infection (a procedure known generally as a mummifying process), the pulp tissue is invariably subject to infection at its peri-apical entrance into the root canal. The virility of the viridans organism is so slight that no active inflammatory action takes place, and pus is not formed. As the *Streptococcus viridans* makes a *habitat* in the foramen at the end of the root, a protecting ring of fibrous tissue is formed around this point. It is a mooted question whether this envelope of the granuloma is intended as a protection to invasion of the tissues, or whether it is a protection to the streptococci against leukocytes or other antagonistic elements.

The fact remains, however, that from these infective foci, toxins may be constantly sent into the rest of the body. It is a very generally recognized fact that the toxins from different microörganisms appear to have a selective affinity for certain tissues. The toxins emanating from these granulomas appear to have such a selective affinity for the muscles and valves of the heart. The most unfortunate feature in connection with this type of alveolar abscess is the insidious manner in which it strikes at the individual's vital forces. Its lack of virulence appears to make it incapable of producing severe local irritation, and consequently a dangerous toxemia may be progressing without the slightest local manifestation.

With the present-day knowledge of mouth sepsis, the physician is much more frequently referring cases of general infection to the dentist for his opinion as to whether a septic focus is present in any part of the dental region.

Heretofore the dentist has simply demonstrated his incompetency in returning a verdict of an aseptic mouth based simply on ordinary mouth examination. Only a careful roentgenogram examination of each individual tooth socket will show the presence of these blind abscesses. The importance of the dental opinion, when a patient has been referred by the physician for a careful examination, has never in the past been properly appreciated. In the future, for a dentist to say that a mouth is free from infection, however beautiful and physiological it may appear, he must first carefully study the roentgenograms of every tooth in the mouth. Unless the dentist has such roentgenograms of the entire jaw and mandible at his disposal for study, he is incapable of giving an answer to this all-important question. The various types of arthritis, ulcers of the stomach, gall-stones and kindred toxic diseases, have had their origin definitely traced to abscesses about the teeth.

PERICEMENTAL ABSCESS.

There is still another form of abscess which closely simulates the alveolar abscess, and may exist for years without interfering with the vitality of the pulp of the tooth in the region of the abscess. It has no etiological connection with the dental pulp. It is called pericemental abscess, because the localized infection is found in the pericementum around the roots of the teeth. The most acceptable theory of the formation of these abscesses is that in the pericementum is left some remnant of the epithelium from which the original enamel germ was formed. These remnants of epithelium become infected in the same manner as does the organic tissue left at the peri-apical end of a root-canal foramen, which produces a blind abscess. Of course no one can say that this theory of the etiology of pericemental abscess will be borne out in the final studies of the cause of this malady. It is, however, of the utmost importance that in the diagnosis of other types of abscess this form of infection be properly excluded. In the past pericemental abscess has rarely been correctly diagnosed. Like the ordinary alveolar abscess, it is most frequently called pyorrhea alveolaris. Many men of ability, who have been able to exclude the symptoms of a pyorrhea, have erred in supposing it to be an ordinary alveolar abscess. Here, also, the roentgenogram has proved of the greatest value in making possible correct diagnosis (Fig. 120).

Treatment.—In the treatment of pericemental abscesses, ionism has been found the most useful agent for their cure. Frequently, however, even though the pulp does not appear to be involved, it becomes necessary to remove this organ before a cure can be effected.

It may not be out of the way at this time to deprecate the growing tendency to the use of the term, pyorrhea specialists. It should be clearly understood that pyorrhea alveolaris is only a symptom of something wrong in the equilibrium of the body.

This something is not always the same thing, and consequently the cure and treatment of different cases of pyorrhea may call into therapeutic requisition any one of all the known dental operations from orthodontia to the introduction of an artificial denture.

Fig. 120. — Roentgenogram of pericemental abscess.

Nearly all of these self-styled specialists begin and end their treatment with the pyorrheal pocket and its environment. Such men succeed in doing an incalculable amount of harm. While recognizing the great benefits to be derived from the various specialties in dentistry in their particular field, the treatment of pyorrhea alveolaris should never be termed a specialty, because its successful therapy may demand the services of not only any one of our recognized dental specialists, but may also require various kinds of medical treatment. In this respect it is of great importance to be able to differentiate between physiological and abnormal gum tissue, not merely in a gross manner, but with all the niceties of gradations in color, texture and atrophy or hypertrophy of tissue. To be able to differentiate healthy from abnormal gum tissue, one must possess minute knowledge of the appearance of these tissues, which is only gained from the experience of repeated observations with this point in view. The eyes of prophylactic operators are so constantly turned on these tissues that they have exceptional opportunities for perfecting themselves in these differential observations. The gum tissue is nourished by terminal capillaries, which leave this tissue as venous blood. The extreme vulnerability of the gums is due to the fact that any impairment in nutrition leaves its first imprint on this tissue.

It has become a well-known clinical fact that the effect of malnutrition upon the gums varies according to the nature of the cause. The simplest proof of this fact is found in the blue staining of the gums from toxic doses of mercury. Physicians for many years, in administering mercury, have been accustomed to look for this blue stain as an indication that medication by mercury has been carried to its limit of safety. In like manner, every grave nutritional disorder in its action of gum starvation, leaves the tissue with a different appearance, depending upon the nature of the organic trouble.

The severity of the disease, and consequent extent of injury to the system, to a certain extent, can be measured by the amount of variation from the normal appearance of gum in each specific case. Some of these variations may be very slight and difficult to differentiate, while others may be widely dissimilar. For example, in Bright's disease the gum, while slightly inflamed, is paler than normal tissue at the gingival portion. Its real specific characteristic, however, consists in a narrow whip-cord-like hypertrophy on the lingual surfaces about one-sixty-fourth inch from the gingival margin, and conforming in contour to the scalloped shape of the gingivæ. In diabetes, however, the characteristic appearance is quite the opposite. The inflammatory condition is much more marked, giving the gums an angry, dark reddish hue around the gingivæ, which latter are very spongy in consistency, and have lost their attachment to the cementum. The gums bleed freely when even slightly irritated. When the mouth has been left open for a very short period, the palatal surface loses its moisture, and assumes a shiny surface similar to the outer skin of an onion. One of the most characteristic diagnostic signs in the dental region is shown in those cases where, on account of valvular disease or other heart disorder, there is an insufficient power in the force of the arterial circulation as it leaves the heart. In such cases the gum, extending from one-third to one-half inch from the gingivæ, will be found to be more or less cyanosed. Above the dark blue area, the gum has the normal pink color. There is no blending of the normal pink color into the dark blue, but an abrupt transition that makes the diagnosis of circulatory trouble of some kind a very simple matter.

The writer has made a diagnosis of many cases of tuberculosis of the lung, simply from observing the abnormally increased excretion from the mucous follicles. This wonderful diagnostic field will be found especially interesting to the intelligent, studious and observing hygienist. It should not be thought that this can be easily mastered. It will take much observation and study to learn to subdivide properly and understand the different appearances in different cases. By taking a sympathetic attitude, and by the use of tact and judgment, it is easy to learn the physical history of these cases, and thus study the peculiar characteristics of the gums in different forms of malnutrition. To the individual who has the talent to master this differential observation, there is opened a wonderful field of usefulness. It lies in the province of the dentist, if he has sufficient ability, to detect incipient signs of malnutrition. It is written in indelible type on the gums long before urinalysis discloses any tangible sign.

It will be one of the great privileges of the dental hygienist to call the attention to these indexes of malnutrition.

It seems scarcely necessary to say that the early diagnosis of many such conditions frequently means a possible cure at that period. Even where that is impossible, it often means a considerable prolongation of life if proper treatment is pursued.

Treatment of Alveolar Abscess.—Alveolar abscesses may be divided into two classes, acute and chronic. In the latter class would come the division of granulomas or blind abscesses. An acute condition of an abscess refers to the initial stage of infection, where for the first time pus is about to form in the peri-apical region. If such a case is seen early enough, the pulp chamber may be delicately opened, and a dressing of tricresol and formalin (formacresol, Buckley) placed in the pulp chamber and sealed in place with oxyphosphate of zinc cement. In a certain number of cases, seen at a very early stage, an abscess can be aborted in this manner. In most cases, however, when such an infection has begun, nothing will prevent its going to the point of resolution with the resultant flow of pus. If left to itself, the pus will follow the line of least resistance and will finally discharge explosively into the mouth. When it is evident that this result is imminent, heat is often applied to hasten the advent of suppuration. It is during this stage of edema and inflammation that the pain reaches its height, and consequently every effort should be made to bring about a flow of pus, and thus relieve the tension of the other tissues. At the very earliest moment possible the infected area is laid wide open, and if this does not result in a ready flow of pus, the alveolar plate is pierced and an outlet established for any pus which may be present. The fistulous canal is now kept open with gauze packing, and after a short time all symptoms of pain disappear. It is now feasible to remove the infected dead pulp, eradicate the pathological condition in the peri-apical region, and leave the tooth in a sound condition and free from the danger of reinfection. In this respect the treatment is practically similar to the cure of a blind abscess or granuloma.

While dental hygienists will take no personal part in the operative procedure of pulp removal, they should have a thorough theoretic knowledge of what is required, not only for the removal of pathological conditions, but also for so leaving the tissues that reinfection is rendered practically impossible. It must be understood that there is a scientific reason for every procedure, and that nothing should be done which is empiric. Too many men of recognized ability have been satisfied with a technic which results in leaving the field free from infection when this operation has been completed. Nothing short of making infection in this locality impossible will give dental surgery that high position to which it is justly entitled in the field of preventive medicine. It matters little what method is pursued if this result can be secured.

To accomplish this object, it is necessary that:

1. Every particle of organic tissue, living or dead, must be removed from the canals.

2. Any diseased tissue in the peri-apical region must be entirely obliterated.

3. Infection of organic structure in the dentinal tubuli must be guarded against.

4. All foramina must be hermetically sealed both within the canal and on its peri-apical area.

5. Infection from the region of the pulpal chamber must be made impossible.

The time has come when it must be recognized that all five of these requirements must be met. No compromise can be permitted in order to safeguard the future health of the individual. If for any reason any one of these results cannot be attained, the tooth must be extracted.

Where diseased conditions have not advanced too far, there are not more than three or five per cent. of teeth that cannot be scientifically operated upon, so that all these requirements can be fulfilled. This result, however, is as a rule only possible at the cost of many hours of work, requiring great patience and skill of a high order. This always has been and always will be the great bar against the practicability of preserving in a state of health the vast majority of teeth with pulp involvement.

Thousands of dentists appear to think that if the interior of the root canal is found free from infection, no harm can result from such a tooth. They appear incapable of appreciating the fact that the little blind abscess at the end of a root with the mildest kind of a streptococcus infection is the most dangerous factor that can be left in the human mouth. It can now be seen that the non-hemolytic streptococcus of low power of virility (so low that it is incapable of producing sufficient inflammation to produce the slightest perceptible irritation) is continuously sending a small quantity of toxins through the system.

It is fortunate that a stage where these facts have been substantiated by exact laboratory study has been reached. No longer can the pompous practitioner assert, "my opinion is as good as yours." He must be made to realize that this subject has passed the stage of theory to one of established scientific proof.

While, therefore, the future practice of dentistry is destined to bring the practitioner back to the point of extracting a great many more teeth, the greater value of the natural teeth over anything artificial must not be overlooked. Efforts at conservation of human teeth should not be lessened wherever such a consummation is feasible.

Although the operative technic of root filling does not come within the sphere of the dental hygienist, the writer feels warranted in giving in detail the technic of the improvement to which he has been giving continuous attention for over thirty years, so that this most important operation in dentistry may be clearly understood. It is his fondest hope that in the future someone will unearth a method that will be less laborious and require less time, but up to the present this procedure appears to meet the demand more thoroughly than any other.

Only since the introduction of the x-rays has it been possible to place root-canal therapy on a scientific basis. It is the most important aid at the command of the dentist today in performing a scientific operation. It is continuously required from the outset to the conclusion of the work. It is important before beginning, to have a roentgenogram that will give a general outline of the anatomy of the roots and indicate if any pathological condition exists, and the visible extent to which tissue destruction has taken place.

The first essential in the mind of the operator, should be that when the operation is completed, the filling material must seal the periapical end of the root, and consequently he must be able to pass a broach through every foramen. To accomplish this it is essential that the point of entrance to each root canal should, as nearly as possible, be on a straight line with the foramen at the end of the root. By the aid of the x-rays this is reduced to a geometric problem, and many teeth can have apparently badly curved roots straightened by making the point of entrance at the correct spot. In attaining this object, no consideration must be given to conservation of tooth substance. Having solved the geometric problem, it is best to remove at the start as much of the crown as it will be necessary to remove at any stage.

After some experience this can be readily gauged. Much time can be saved, the work can be made less difficult, and better results can be obtained if the operation of removing every portion of tooth to be removed is completed before any canal is entered. There are cases in which it may be necessary to remove the entire crown, and where a root is to be crowned, it is naturally far preferable to do this at the outset. The operator must become thoroughly familiar with the ordinary anatomy of the different teeth so as to expedite matters as much as possible. Where living pulp is to be removed, it is supposed to be previously anesthetized. Before the pulp chamber itself is entered, the rubber dam should be adjusted and the field of operation carefully washed with alcohol or a ten per cent. solution of formalin. Every possible precaution should be taken to insure strict asepsis at every stage of the operation. If a live pulp is to be removed, a perfect Donaldson bristle is selected, after the barbs have been carefully scrutinized under a magnifying glass to insure against the fracture of a defective broach. The fine Donaldson barbed broach is then passed gently alongside of the pulp tissue as near the end of the canal as possible. Only practice can bring the skill that the delicate manipulation of this broach requires. It might be said that firmness and exquisite delicacy of manipulation is a combination of application that is necessary in the use of the broach.

It is requisite, in the manipulation of the broach or in any other form of canal instrumentation, that the operator's attention should never be deflected in the slightest, because of the danger of breaking an instrument in a root canal.

The same care in instrumentation is necessary if the pulp be dead. Under such circumstances, too much attention cannot be devoted to avoiding the forcing of any infected material, however minute, through the foramen. It is frequently an error of judgment to prolong instrumentation too far. After the removal of all masses of tangible tissue, whether living or dead, or in any particular degree of decomposition, chemical measures must be employed.

For this purpose recourse may be had to sodium and potassium, (kalium-natrium). This unique mixture of metals was made by Dr. Emil Schreier, of Vienna, over twenty-two years ago, and to those who have learned its merit, it is unquestionably the most valuable means at our disposal in root-canal therapy. It has an intense affinity for water, and as a result unites with any form of organic matter with such great avidity as to produce immediate oxidation of everything connected with the union. Thus, a given quantity of sodium and potassium unites with a given quantity of organic tissue, and the result is complete destruction of that much organic matter. Only a portion as large as a pin-head should be introduced at one time, on account of the violent reaction which takes place. In the case of a putrescent canal, as soon as a point has been reached where there is the slightest danger of forcing infection through a foramen, instrumentation ceases, and sodium and potassium is utilized. On the end of a barbed broach a very small quantity of the medication is introduced into the canal. The result is flame, smoke and gas, and when this has subsided we introduce another particle, our broach constantly passing nearer the end of the root, until finally every particle of putrescent matter has disappeared, and the broach has passed through the foramen. Properly carried out, one need not fear, with this technic, that septic matter may be forced through the foramen, and when irritation results, which rarely occurs, it will subside within from twenty-four to forty-eight hours.

In the removal of living pulp tissue, the sodium and potassium unites and destroys all of the numerous shreds of organic matter that are found at the orifices of the dental tubuli. This destruction proceeds some distance into the tubuli. Only when all chemical action has ceased, and the broach has passed through the foramen, can it be said that the canal is void of organic tissue. In the removal of living pulp, this result is never possible until the second or third sitting. There is then no longer any anesthetic condition, but generally some sensation remains until the last particle of pulp has been removed, when what is left of the medication becomes inert in the canal.

The greatest value of this material is found in chemically reaming such canals as appear impossible to penetrate on account of being occluded with calcified matter. In all such cases some organic matter is always present even if it is not perceptible to the naked eye. As long as the slightest moisture is left, the kalium-natrium will destroy this stratum of tissue. When at times the kalium-natrium becomes inert on account of the absence of moisture, it is necessary to moisten the canal with a few drops of distilled water. After some progress has been made in blazing a path in the canal, a fine, sharp-pointed instrument, made of superior hard-tempered steel, is introduced into the fine opening. These instruments are called dental picks, and with the organic strata removed, it is not difficult to break up the calicified mass into very fine fragments, which cling to the picks and are readily removed when fresh sodium and potassium is introduced. The repetition of this technic will finally succeed, not only in carrying the broach through the foramen, but also in widening the canal sufficiently to make it readily accessible to the canal plugger. Often it is impossible to pass the broach through all the foramina until the patient has had a number of sittings.

The operation can cease at any point. The use of sodium and potassium has rendered the canal aseptic and no medicament of any kind should be placed in the canal. The general practice of sealing in the canal some antiseptic remedy cannot be too strongly discouraged. If there is any abnormal pathological condition at the apex, it will usually be obscured by the drug. Then, again, it interferes with that absolute cleanliness of root structure which the operator is exerting every energy to attain. When ready to dismiss the patient, a fine gold wire should be passed up the canal as far as possible through the foramen, when this can be done. The external end of the wire is then bent so as to make it easily removable. A small dressing of sterile Japanese paper or cotton is now packed around the wire to prevent the ingress of filling materials, and the cavity is sealed with base plate gutta-percha. The tooth is then radiographed and the picture discloses whether the wires have passed through the foramina, and if not, how far they are from the root end (Fig. 121). Not infrequently it will be found necessary to cut away more tooth structure in order to permit the broach to enter at the correct point, which the gold wire now for the first time discloses.

Fig. 121. — Roentgenogram showing gold wires through the foramina.

These wires become most valuable for diagnostic purposes in teeth having pulp nodules and canals impacted with calcified matter.

A stage has now been reached where it can be consistently said that the canals are clean. The roentgenogram shows the wires through every canal foramen. The canals are now washed out with a solution of 1 part of sublimate to 500 parts of hydrogen peroxide (Marchand or similar). This solution, after the canals are dried, will leave traces of sublimate along the orifices of the tubuli.

If there is any diseased area in the peri-apical region, it has not up to this time been disturbed, but is now ready for extirpation. The canals are now flooded with physiological salt solution. The negative pole of a galvanic rheostat, properly constructed for this purpose, is now attached to some part of the cheek by means of a wet sponge (Fig. 122). The positive pole consists of a wire of chemically pure zinc, which is held in the different canals in turn. Care must be taken not to allow the zinc point to pass through the foramen or to occlude the opening, so that it may not interfere with the egress of gases (emanating from the peri-apical area when the granuloma or other form of pathogenic tissue is being destroyed) through the tooth. These rheostats are worked by a shunt system, so that the amperage can be gradually increased without causing any discomfort. One or two milliamperes of current is generally easily borne, and the anode should remain in each canal from five to twenty minutes.

In this manner ions of electricity, together with nascent chloride of zinc, are forced through the foramina. The tubuli themselves are thus placed in an absolutely germicidal state. Any ordinary granuloma can be entirely obliterated in this way, to be followed by the growth of new alveolar structure if no place is left for any invading bacteria. When, however, the cementum of the root itself has become necrosed, apicoectomy must be resorted to after the root filling has been completed.

The root canals are now ready for filling. The first essential for the root filling is that it should be easily forced through the foramen; it should be most compatible to the dental structures, indestructable and void of any irritating properties. As long as the filling material fails to encapsulate the outside of the end of the root it is inviting reinfection.

Paraffin always presents the possibility of becoming absorbed, and is therefore contra-indicated. Cements composed of oxychloride of zinc, or containing any irritating substance like formaldehyde, are contra-indicated. No cement substance can be depended upon to fill compactly every crevice and deflection of the normal canal, to say nothing of the miniature foramina that are found. The frequent discovery of foramina on the side of the root makes it essential that the canal should be filled with a solid homogeneous mass, unchangeable in its nature, and which will hermetically seal the mouth of every dentinal tubule.

Gutta-percha meets the requirements of an ideal root filling better than any other material. Points made from base plate gutta-percha are selected of a diameter which will enable them to go to the end of the canal. They are placed in a 10 per cent. solution of formalin, so that their surfaces will be aseptic. The canals are thoroughly dried with warm air. A fine broach, upon which are twisted a few fibers of cotton, is dipped in a very liquid solution of chlora-percha; this is carried to the very ends of the canals. With an aseptic pair of tweezers

Fig. 122.—Specially designed rheostat.

the gutta-percha point is taken from its bath, is carefully dried in an aseptic napkin and gently carried into the canal. A plugger, which will pass to the end of the canal, is dipped into alcohol, ignited at a lamp, and the warm plugger firmly but delicately forces the gutta-percha point to the end of the canal. One or two more fine gutta-percha points are introduced in this manner. A small piece of Japanese paper is then twisted around the plugger; this is soaked in chloro-

Fig. 123.—Roentgenogram showing end of roots encapsulated with gutta-percha root fillings.

form, then passed into the canal, and the gutta-percha repeatedly packed with this chloroform tampon. This causes the gutta-percha to become soft and, under pressure, makes it pass through the foramina and into every depression. Fresh gutta-percha points are treated in the same manner until the filling is complete. With cold air every particle of chloroform is volatilized, and it is then covered with an oxychloride of zinc cement in order to prevent infection through the crown.

Fig. 124.—Roentgenogram taken two years after abscess had been eradicated by ionism. It shows regenerated alveolar structure and protruding gutta-percha root filling enmeshed in the bone cells.

The tooth is now again radiographed in order to determine if the end of the root is encapsulated with chlora-percha (Fig. 123). If the root filling has not passed through the end of the root, it becomes absolutely necessary to remove all of the root filling and again attempt a correct filling. The final roentgenogram is essential in determining whether the tooth has been left safe from the possibility of reinfection. When this procedure has been correctly carried out, there can be no possibility of reinfection, and in time new alveolar structure will be found in the peri-apical region, as is shown in Fig. 124.

There remains one class of cases in which it is impossible to eradicate the pathological condition by means of ionism. Whenever any part of the cementum of the root is necrosed, surgical interference becomes imperative. Usually nothing short of root amputation will absolutely cure these cases. Unfortunately it is not always possible in the reading of the roentgenogram to know whether or not the root surface is necrosed.

The great advantage in being able to cure such a large number of peri-apical infections by ionism makes it better practice to try ionism in all doubtful cases. When this has failed, root amputation takes its place as the correct procedure. It must, however, be understood that like all other measures, it must be applied in such a manner that no pathogenic spot remains. Imperfect surgical operations are, like imperfect root-canal technic, absolutely valueless to the patient.

CHAPTER XII.

DENTAL PROPHYLAXIS.

By ALFRED C. FONES, D.D.S.

THE CELL.

In order to appreciate health it is necessary to be familiar with the facts concerning the individual cell, and the effect of various influences upon the unit must be studied before an understanding can be had of the action and influence upon the cells in the aggregate. If a drop of water is taken from the side or bottom of an aquarium and put in a glass under the microscope, a minute jelly-like mass may be seen. Its outer circumference slowly changes its shape, while near the center there is a very minute globule termed the nucleus. This is the lowest and simplest form of animal life and is known as the ameba. This simple cell has seven distinct properties. It may extend its wall in projections like false feet or protuberances or may flatten itself out in a long line, therefore it has the property of elongation. When irritated by being brought into contact with dilute acid it will contract into a round form; hence, it has the property of contraction. These two properties give it its power of motion. It appreciates the presence of irritants, of food and of thermal changes, therefore it has the power of sensation. It can digest food and discard waste tissue, therefore it must have the properties of secretion and elimination. The cell and nucleus have the power of dividing themselves in two, thereby forming two cells. It has the power of reproduction, and the new cells have the property of growth.

When all of these functions or properties of this simple cell are working normally, the ameba is in a state of health or balance. Rob it of one or more of its properties and it is diseased. Stimulate the cell by applying certain agencies and its motions become more rapid, it consumes its food more rapidly, it will subdivide and reproduce itself more rapidly. A greater stimulant will cause a still greater activity, but if this is continued the cell soon becomes exhausted and paralyzed from exertion and the ultimate result will be death. The reverse takes place under sedation produced by applying cold. The motions become slower, also digestion and reproduction. If the temperature is dropped too low, the cell dies. Pollute the water or rob it of its oxygen and the cell dies. Cell life is maintained chiefly by a chemical process of oxidation. It must have water and it must have a food supply to replace the lost substance which is gradually being utilized in performing its various properties and functions. It is therefore apparent that cell life is dependent upon oxygen, water and food, a proper temperature and removal of waste matter.

Nature, in the building of all matter, builds from the unit. Although the atom is the smallest unit, the molecule of the mineral kingdom and the cell of the animal and vegetable kingdoms are the general bases for study. All earthly creations visible to us are formed on this one plan. The trees, the flowers, the grass, the mountains, the beach, the sea, all animal life, including man, each is made by the combining of these units, all working with an intelligence and subject to chemical laws far beyond our comprehension.

Why it is that the contents of the cell, which is called protoplasm and which appears to be nothing but a jelly-like mass, has the property of manifesting life and intelligence, is difficult to understand. This substance can be analyzed and even the proportion of its elements estimated, yet what unseen force imbues it with energy and intelligence and what becomes of this life-giving power when the cell dies and disintegrates, is not known. Cell action can be studied, and the cell can be supplied with the essentials for growth and development. It is a realized science that in animal life, certain factors properly applied at the proper age can greatly develop its function and intelligence, the same as in vegetable life, but it cannot be explained. It is known that all manifestation of life and of intelligence is expressed through this matter contained within the cell.

In the gradual evolution of these simple cells like the ameba, combining to form larger and more complex organisms, it is found that the cells choose a specialty of two or three of these properties, and those whose specialty is the same are grouped together. As animal life develops into higher planes the cells become more proficient in their specialties, until in man is found the greatest variety of highly specialized cells in animal life. While the ameba possesses a balance of seven properties, some of the specialized cells of man concentrate on but one function. It may now be seen how these cells of man that have undergone a slow evolution of millions of years to reach their present degree of intelligence are reflected in this low and simple order of life—the ameba. It has been stated that the ameba has seven properties. Its power of contraction is exemplified in the muscle cells of the human body, whose specialty is contraction. These cells are capable of wonderful development and training. The finger touch on the piano keys, the surgeon with his instruments, the dancer, the juggler, the athlete, the artist, and the artisan, all demonstrate how these minute individuals receive impressions from the brain and nerve centers and interpret them with such wonderful intelligence. The nerve cells specialize on the transmission of sensation and vibratory influences to and from the brain. Digestion and elimination, being very much more complicated in higher animal life, require innumerable cells which perform separate functions—the passing on of food, the secretion of fluid for its solution and its preparation for absorption. In the blood stream are cells floating along, each intent on its special duty. The liver, with its cells actively engaged in preparing the waste products for elimination by the kidneys, the sweat glands, the lungs, the brain (that wonderful terminal station, headquarters for all orders), all are composed of these specialized units working together like so many people in an immense city, each adding his mite in labor and service for the common prosperity and health.

The intelligence displayed by the individual cells of the body is the marvel of scientific investigators in physiology and pathology. Much is yet wrapped in mystery and many years will pass before some of the deep problems of nutrition and the hard-fought battles waged against disease will be fully understood.

When the body is abused this abuse is imposed upon millions of intelligent beings who do their utmost to offset ignorance and wilful acts by patiently combating the impositions and trying to correct and repair the damage wrought. In early youth the cells are in abundance and the supporting structures are but partially formed. In adult life the work of the cell is completed, and the intercellular structure is in predominance. The great period for structure building and for the guidance of proper cell development, physically and intellectually, by applying scientific factors to properly influence this result, is from infancy to twelve years of age.

As a spider spins his web so do these minute cells create tissue to aid them in their work. The individual reflects the composite texture and make-up of the aggregate cells of the body, and the period for molding, refining and advancing this cell development to its highest plane is in early youth.

Factors for Cell Life.—The scientific factors for influence are numerous, but there are a few that stand out conspicuously. First of all comes pure air, for cell life is dependent upon constant oxidation. Next comes a proper food supply. The character of food will eventually determine the character of the cell, and as the body is physically composed of millions of cells, the food supply in a great measure determines the character of the individual. This is exemplified in the glutton, the drunkard or the savage. *What* is eaten, *how much* is eaten, and the *manner* in which it is eaten, are some of the chief factors for health balance. The question of food values, the quantity consumed and the importance of thorough mastication and insalivation should be a study for all hygienists.

Next comes cleanliness, for if disease is to be prevented clean food, clean water, clean mouths, clean bodies and clean environments are necessary. Mental attitude is another powerful factor and should have fourth place. Self-control, optimism, that mental poise that can discard fear and worry, that holds an even balance under varying circumstances and that can radiate good cheer and kindness through their health-giving influences to every cell of the body, are elixirs unequaled in the building of the character as well as in regulating a perfect balance and functioning of the entire system.

Although heredity, too, plays a strong part, yet the first four factors named can greatly modify the inherited disposition of the cells if wisely applied. When we speak of coarse natures, we speak of an unfortunate inheritance of a type of cell life that might have been greatly softened and modified in childhood.

Exercise is also exceedingly important, for rest means rust even in animal tissue.

If man lived what is termed a "natural" existence, which means, in other words, an outdoor and primitive life, with simple coarse foods and work or exercise in the open air, which develop the animal side, there would be but little need of the physician or the dentist. The coarse food would mechanically clean and polish the teeth by friction, and the out-of-door exercise or work would cause an enforced breathing which would mean a greater intake of oxygen to burn up the slag and waste products in the system. But this so-called natural existence is not possible to 70 per cent. of the people of the present day. Their very existence depends upon their work or artificial life in the cities, and the yearly increase in numbers in the cities rather proves the preference for the city over the country. Therefore this health problem of city life must be solved. The factors which are productive of health in the animal life must be substituted artificially. The passing generation cries that children are being brought up too much by the teaching of science and the book instead of in the good old-fashioned way of letting nature look after them. Take, for example, the wild rose of the field that depends upon sunshine and shade, warmth and moisture and proper soil for its growth. Nature does not and cannot always supply these in sufficient degree and in proper balance, and although the flower is beautiful it cannot be compared with the beautiful rose that the horticulturist can grow when these essentials are scientifically and artificially supplied. In the hot-house the correct temperature can be maintained, moisture in sufficient quantity supplied, sunshine and shade regulated at will and fertilizers essential to stimulate growth added to the soil. The work of Burbank in scientifically handling vegetable life is well known and our modern methods of agriculture and fruit raising. The wonderful feats of the horse, hurdling, running and trotting are due in great measure to the scientific training by man. Many instances can be given in which nature far excels her natural state of environments if the essential factors she needs are supplied artificially and scientifically in sufficient abundance and degree.

And so it is in the growth and development of the city child, and even in that of the adult. If the proper factors for health can be scientifically administered, it is possible to grow children as far superior to those of the present-day average in the public schools as the American Beauty is superior to the wild rose. Man has had his progressive period; woman is having hers. The coming one belongs to the children.

THE ALIMENTARY TRACT.

Before confining thought and attention chiefly to the teeth and their surrounding tissues and considering how disease may be prevented, a few simple thoughts regarding the body must be presented, that it may be better understood how important a part the mouth plays for health or for disease. There is no better way of doing this, perhaps, than first to consider a country with its many people, and show the factors upon which it is dependent for health, for a close analogy may be drawn between the life of a simple cell, the individual and the nation as a whole. Egypt is the best for illustrating this thought, for here is found a strip of life running through a region of apparent death. Suppose a piece of green cloth, six inches wide and a hundred feet in length, was laid on the sands of the seashore, running straight upon the beach from the water's edge. If in the center of this cloth was laid a long white string to illustrate the river Nile, it would be a fair representation of Egypt. The Nile runs through a desert and the water with its life-giving power has created a living body close to its borders. In this living body are millions of people who are dependent upon this alimentary tract or river for their existence. Along the banks may be seen the water buckets, operated by the natives to supply their fields and gardens. In the season of the overflow the soil is soaked with moisture, the crops are plentiful and there is ample for those who will work. Canals or arteries lead from the river bank across the fields to supply life and growth to the soil that would be desert waste without it. If it were possible to poison the source of the Nile so that its waters carried their life-giving properties no longer, but contained some chemicals that were destructive to plant life, or sufficient sewage to poison the inhabitants, Egypt would soon cease to exist. Just in proportion to the amount of poison carried down the river would the country and people suffer from starvation and disease. The bodies of all animal life are constructed around their alimentary tract. The lowest forms of cell life when changing to a higher organism, find it essential to develop first a mouth and digestive tract, for the intake of food is of first importance with all material life. The body with its millions of cells is dependent upon the flow of nourishment through the alimentary tract and as the individual lives and feeds so will his body thrive or deteriorate. The mouth is the vestibule or gateway to the whole system. All the nourishment and food supply to the body must pass through this one portal. The placing of the food in the mouth is a voluntary action and it can be controlled as long as it remains there, but the moment it is swallowed it is beyond voluntary control and is sent on that mysterious journey called digestion, absorption and assimilation.

Assuming, first, that the food eaten is clean and pure and above criticism, and enters a clean mouth, is properly masticated and swallowed, digestion takes place normally, provided the mental attitude be one of tranquility during this period. If the mind is excited or irritated, it will send depressing messages throughout the body and the process of digestion is retarded and disturbed.

Under such clean conditions the normal processes of digestion can take place with a minimum amount of effort and energy being expended by the tissues in their work, and the product after digestion is fit for the blood stream to offer to the cells of the body the nourishment they need to perform properly their respective functions. But the reverse situation exists regarding the mouth. The food may be clean and pure but the mouth unclean.

Decomposing Food Débris.—In discussing the harmful effects of decomposing food in the mouth, the subject cannot be better presented than by giving some of the thoughts of Dr. E. C. Kirk from a paper read by him in Providence, R. I., October 16, 1900, and published in the *Dental Cosmos* in May, 1901, entitled "Some Considerations Relative to the Infant Mouth."

Regarding the artificial feeding of infants he refers to the training of the nurse to sterilize the milk and feeding apparatus in order that the milk shall be delivered to the child's stomach free from bacteria "which when present in the food supply so alter its composition as to reduce its nutritive value and, what is still more important, set up decomposition processes within the alimentary tract of the infant which are direct causes of irritation and disease to the infant organism."

Great care having been taken in preparing the food and in feeding, no attention was paid to the film of milk left in the mouth after feeding. It is apparent that if fresh milk is poured into a bottle that has contained sour milk, infection of the fresh milk will immediately take place. In the feeding process the sterile milk passing over the infected surface caused by the residue of the last feeding at once infects the milk.

Dr. Kirk says, "There can be but one result; fermentation of the infected fluid begins in the stomach; putrefaction of the proteid elements may take place; quantities of gas are formed, distending the walls of the stomach and intestines, causing pain and irritation, further increased by the irritating effects of organic acids which are end-products of this fermentative process. Digestion is interfered with or arrested, the fermenting mass of food becomes a mechanical as well as a toxic irritant; diarrhea sets in, the whole nutritional process is interfered with and development is damaged in proportion to the length and severity of the attack.

"The rational remedy for this state of affairs is clear when once the conditions to be therapeutically met are understood. In the first place, removal of the primal cause by thorough oral cleanliness and sterilization in so far as that end may be obtainable. This may be practically accomplished by wiping the mucous membrane with a saturated solution of boric acid to which borax has been added in the proportion of ten grains to the ounce, or with a very dilute solution of phenol sodique, one-half dram to the ounce, applied on a cotton swab or with a soft linen handkerchief wrapped around the finger of the nurse."

Now apply the same principle to the growing child and to the adult. The teeth of a child between the ages of six and twelve years will present surfaces equal to twelve to sixteen square inches. In an adult the surfaces will average about twenty-five square inches. This means that if it were possible to peel the enamel off of each of the five surfaces of each tooth and place them side by side they would cover a piece of glass three and one-half inches square in the case of the child, and in that of the adult a piece about five inches square. This will give a rough idea of the amount of surface presented in the mouth to permit of the retention of a certain quantity of food that must decompose unless it is removed. The more perfect the teeth regarding form, occlusion and enamel surface, the more self-cleansing they are, and proportionately, the amount of food so retained is comparatively small. The mouths that present such ideal conditions are rare, especially among those who are born and live in the cities. Where the teeth are irregular in shape and position, are decayed and broken down, the amount of food that remains is considerable and the volume of decomposing material constantly being swept into the intestinal tract will eventually breed illness. In a growing child such mouth conditions are vicious. "Suppose," said a prominent educator in dentistry, "that a prescription was given to a mother by a physician, to mix, with each meal that the child ate, a half-spoonful of garbage. Would she carry out such a prescription, and if she did and the child became ill, would not the physician be liable for damages?" And yet in reality that is what is taking place in the average mouth of the children in our public schools and in the mouths of the great working classes. This constant drain of poison into the intestinal tract in child life causes an intestinal indigestion where bacterial products are absorbed into the system and produce fevers, headaches, eye-strain, anemia, malaise, constipation, and dizziness, Nature finally takes away the child's appetite and forces it to bed until a good house-cleaning of the body can be accomplished.

These poisons from the mouth are insidious and slow in action. Many can and do withstand them for years, but as the constant dropping of water will wear away the stone, so will the products of decomposing food in the mouth soon destroy good digestion and undermine the system.

Vaughn and Novy, in their book entitled *Cellular Toxins,* say, "The effect of a chemical compound upon the animal body depends upon the conditions under which and the time during which it is administered. Thirty grains of quinine may be taken by a healthy man during twenty-four hours without any appreciable ill-effect, yet few would be willing to admit that the administration of this amount daily for months would be wise or altogether free from injury. In the same manner the administration of a given quantity of a bacterial alkaloid to a dog or a guinea pig in a simple dose may do no harm, while the daily production of the same substance in the intestine of a man and its absorption, continued through weeks, and possibly years may be of marked detriment to the health."

It must be borne in mind that the manifestation of sickness does not come from the presence of bacteria, but from the poisons generated by the bacteria.

Abbott in his book on *The Principles of Bacteriology*, quotes Roux and Yersin who claim that the potencies of the poisons that have been isolated from cultures of Bacillus diphtheriæ have been determined by experiments upon animals, and it has been found that 0.4 milligram is capable of killing eight guinea-pigs. Please remember that four-tenths of a milligram represents but $\frac{1}{160}$ part of a grain. Aside from the products of decomposing food in unsanitary mouths we must seriously consider how much of the bacterial poisons may be generated in such mouths daily by the millions of microörganisms present, and whether these poisons are not of sufficient quantity eventually to weaken the organism and render the body susceptible to infection from the pathological group of microörganisms. In the battle being waged against tuberculosis, this feature will be given much importance and the day is not far distant when some scientist will be able to compute with a reasonable degree of accuracy how much bacterial poison can be generated in twenty-four hours in a mouth containing decayed teeth and food débris.

Bacterial Propagation.—In considering the products of decomposing food with their detrimental action on the system, their action upon the human mouth, than which there is no better breeding ground for germ life, must also be considered. The mouth is an ideal incubator, for here we find all of the essentials for the propagation and development of these microörganisms. The right temperature, sufficient moisture, air, darkness and a menu to choose from that would tempt any member of this large family. Germ life is comparatively harmless when robbed of a food supply, but give it a pabulum upon which to feed, develop and multiply, and it becomes active and virulent. It must be borne in mind that all mucus-lined tracts of the body have their flora of microörganisms and that the individual must live among them, that the few friendly ones are company, but that too many are a crowd, and that in this crowd are our enemies who feed upon the host if they but get a chance.

An unclean mouth means an increased number of bacteria, and with increased numbers come increased dangers from infection. The cavities of decayed teeth harbor millions of these mischief-makers, as do also the food débris and calcareous deposits around the necks of the teeth. They may enter the mouth in a very subdued state, but under these favorable environments they soon multiply rapidly. The usual order is to consider their activity and growth in unsanitary mouths, but this will be reversed and the medium upon which they best are cultivated in the laboratories be first noted. The saprophytic class are those which exist upon dead animal or vegetable matter. The parasitic class prefers to gather its nourishment from the living host. Many of both classes can live in either medium, as occasion demands.

As the unorganized ferment of gastric or intestinal digestion has the power of changing the food by rearranging its elements, usually by a process of hydration, so do these microörganisms have the power of breaking down tissue or decomposing food and liberating its elements in their search for carbon and nitrogen. The media chiefly used in laboratories for cultures of microörganisms are bouillon, gelatin, agar-agar, potato, sugar and blood serum. If these are kept at the right temperature at least to grow mixed cultures, the saprophytic class is quite easily developed, for the extracts of beef, sugars or starches form an attractive pabulum. Many of the parasitic variety can also be grown in these substances, such as the typhoid bacillus, anthrax and others, while the tubercle bacillus and the bacillus of diphtheria are cultivated in the blood serum. These culture media with the exception of agar-agar, are all found in the average mouth. even to the blood serum.

When the teeth are decayed the amount of food retained in the mouth is considerable, but especial attention should be called to congested and bleeding gums. Here is an ideal medium for the propagation of infectious germ life, and it is not only the cavities in the teeth and the food débris, but also the pernicious condition of the gum tissue in unsanitary mouths, especially in those of children, that is of serious concern. The germs of tuberculosis or of diphtheria can here find a pabulum for their propagation and development, and undoubtedly the prevailing condition of the gingival borders of the gums is one of the most important steps toward infection. The bleeding and congested gums and the decomposing food is present, all that is now necessary is the bacterium.

All observant practitioners will readily agree to the statement that mouths that contain no congested areas on the gingival borders of the gums are exceptions. The dark red surfaces will bleed upon the slightest pressure, and in between the molars and bicuspids where the food can lodge undisturbed in ill-kept mouths, even a slight suction will start a copious bleeding. It will be the privilege of the hygienist to note in the treatment of each new patient how easily the gums will bleed upon the slightest touch of instrument or porte polisher. The oozing of serum and blood from these congested points is of equal importance in the consideration of infectious diseases of children as the decomposing of animal and vegetable matter found in the decayed teeth or around their surfaces. To those who have thoroughly investigated the subject, the mouth is now conceded to be a most important field for bacterial growth and systemic infection.

Tuberculosis.—One of the greatest battles being waged in preventive medicine is the fight against tuberculosis, and this fight can never be won as long as the mouth conditions of the mass of the people remain as they are at present.

Examine the mouths of the children in our large cities who leave school, say, at fourteen and fifteen years of age, and you will note that at least 50 per cent. of them have lost or are losing their molar teeth through decay. At the very start of their lives, then, the nutritional system is handicapped by the lack of power of the teeth to crush properly the food which enters the alimentary tract. The bolting of food becomes a habit, the stomach is daily called upon to dissolve large particles, which means that the blood is retained in the stomach much longer than otherwise necessary, the glands become overworked in secreting sufficient gastric juice, an extra supply of blood is maintained in the digestive tract longer than necessary, and this means a lessened amount of energy to expend in physical and mental work.

As to young women employed in factories, the sedentary life only adds to the weakening of the vital forces, especially if the ventilation is poor and the environments depressing. Add to this the lack of sanitation found in such mouths and we can understand why it is that housewives rank second on the list in tubercular sanitariums, shop hands exceeding them in numbers by a small margin. When these women marry and bear children their forces are still further lowered until their resistive forces are so weakened that infection is a very small matter. The offspring of such a parent must necessarily be a weakling, especially in youth, and its tissues most susceptible to tubercular infection. People so seriously lacking vigor, life and good spirits become the great "sick" class, and this class spells but one word —poverty.

Much stress is laid upon insufficient quantity and poor quality of the food supply as a great causative factor in this disease. This condition is brought about more through ignorance than because of lack of funds with which to purchase proper food, for the body can be well nourished daily for a very moderate sum if judgment and knowledge are used in the buying.

Scientific investigators are now agreed that tubercular infection takes place through the intestinal tract much more frequently than previously surmised. In fact many pathologists insist that this is the chief path of infection. If this is true, the bacilli must either be taken in with the food supply in sufficient quantities to prove dangerous, or they must find lodgement in the mouth in decayed teeth or congested gum surfaces where they become numerous and aggressive. In our state sanitariums where the tubercular patients are segregated, the mouth conditions are deplorable. It is true that with plenty of fresh air, good food and rest, the body can and does neutralize much of the poison. The resistive force is increased and the disease is pronounced arrested. The word cure is cautiously used.

Could the mouths of these patients be made sanitary at the beginning of the treatment and rigid rules enforced regarding their daily care, a marked benefit would surely be observed.

Systemic Infection.—If syphilis and wounds of the surfaces of the body are excluded, there are but three ways, ordinarily, for bacteria to gain entrance into the blood stream: (1) through tooth passes, such as root canals and diseased peridental membranes; (2) through the tonsils, and (3) through the intestines. Infection through the tonsils or through the intestinal tract is dependent in a great measure on mouth conditions. If unsanitary or septic conditions exist in the buccal cavity, many bacteria in a state of virulency are constantly drained over the tonsils and into the stomach. Any physical depression that lowers the normal resistance of the body, might permit of the invasion of these pathogenic organisms. When the mouth is clean and wholesome, the liability to this form of infection is greatly lessened. The greatest sources of systemic infection are through the root canals of decayed and pulpless teeth, and infected peridental membranes. A streptococcus may be non-pathogenic and non-hemolytic in the fluids of the mouth, yet, if ingress be found through the root canal to the apical space, the character of the organism may undergo a change and become pathogenic in its new environment. Bathed in serum and compelled to secure nourishment from the new source, it may develop the power of dissolving blood. If conditions are favorable and it is swept into the blood stream through the lymphatics, or if it penetrates the walls of the capillaries, its lodgement in some other tissue or organ of the body will set up a local and a systemic disturbance that will cause a serious illness, with possible death, to the individual.

Pyorrhea alveolaris is an infection of the peridental membrane. Should the tooth become loosened from the disease, and pus exude from the socket, the play of the tooth up and down in its socket during mastication acts like a pump, and forces the bacteria through the walls of the capillaries into the blood stream. Another short period of scientific investigation will substantiate the fact that tooth passes constitute one of the greatest sources of systemic infection.

In order to secure all possible results from practising mouth hygiene, our efforts should be concentrated upon the children in our public schools. Here we will find the source where most of the evils of adult life have their origin, and not until this work is started and seriously carried on in our public schools can we hope to wipe out infectious diseases, or preserve the teeth, or get control of dental decay with its attendant ills.

Seemingly defective eyesight in childhood is commonly caused by the poisonous products of mouth infection absorbed from the alimentary tract. What seems to be astigmatism disappears when decayed teeth are filled, mouth hygiene practised, and the digestive tract cleaned up.

Anemia can in a great measure be traced to the same source, and there is no doubt but that better mouth conditions will greatly aid the medical inspectors to solve this problem.

THE PRINCIPLES OF DENTAL PROPHYLAXIS.

The initial cause of nearly all the pathological or disease conditions of the tissues of the mouth is the combination of microörganisms and food débris. Bacteria alone or food débris alone would be quite harmless in the mouth. Nearly all germ life, in order to become virulent, or its presence dangerous or even objectionable, must have a pabulum upon which to thrive. It is therefore dependent upon some attractive food supply in order to reproduce and multiply. It is known that foods will "spoil" if allowed to remain in a warm temperature for any length of time, and that in order to prevent this action the germs are killed by boiling or heating the food, tightly sealing it from the air in cans or jars that have just previously been boiled or have had boiling water poured into them, and allowing them to stand long enough for their surface to become sterilized.

Food may also be placed where it will be kept cold, as in an ice-box, where the presence of the ice will so reduce the temperature that the organisms are rendered sluggish and inert.

For years, many efforts have been made to find some drug or chemical that could be used in the mouth to kill all bacteria, and thus make the mouth sterile, or at least to render them inert. The futility of even hoping for a sterile condition of the mouth has long since been demonstrated. It is impossible to sterilize the human mouth, and even if it were possible, such a condition could be maintained but a very short time. Therefore, if it is impossible to keep the mouth free from bacterial life, and as the combination of food débris and bacteria is the chief cause of dental diseases, is there not some way in which the food débris can be thoroughly removed? It is upon this thought that the principles of prophylaxis are based.

Dental prophylaxis is that scientific effort, either operative or therapeutic, which tends to prevent diseases of the teeth and their surrounding tissues. Correcting and restoring to normal function all abnormal or pathological conditions of the teeth, and maintaining that normal condition, is a prophylactic procedure. This includes practically all the operations in dentistry. The mere filling of a tooth cannot be termed prophylactic unless the operation is performed with a knowledge and skill that tends to prevent future decay at that point and that will restore the surface of the tooth to normal contour and normal function. Crowns and bridges, root-fillings, approximal fillings with proper contact points, and smooth, flush margins, the correction of malocclusion, the removal of all calcareous deposits, polishing, the instruction in the proper home care of the mouth, may all be made prophylactic if properly done.

Field of Service.—The exposed surfaces of the teeth, the necks of the teeth directly under the free margin of the gums, and the gum tissue itself, are the parts of most concern to the dental hygienist. Bearing in mind that from now on the battle is to be one of extreme cleanliness on the one hand, and on the other an effort to starve and render inert the bacteria, the mouth of the average adult may now be examined. It is first noted that the enamel is without luster and covered with a pasty and colorless film. The necks of the teeth are stained; calcareous deposits are seen on the inside surfaces of the lower incisors and also on the buccal surfaces of the upper molars; if there are gold fillings, they are tarnished and spotted with dark stains; other fillings in the teeth are rough and the margins are extended beyond the tooth surface so that they hold particles of food débris. The gums are quite a deep red in color, especially upon the gingival borders, and if they are pressed upon even lightly by an instrument they will bleed. Between the teeth may be seen food débris, and at these points the gums will bleed copiously if wounded. Even if there are no decayed surfaces of the teeth, although the chances are there are many, the whole mouth presents an unsanitary condition that means a breeding-ground for millions of microörganisms and a menace to the health of the individual. It must be borne in mind that these people should not be censured for this condition of their mouths, for the chances are they have never been trained or taught how to care for them properly. No one has taught them how to use the tooth-brush or the floss. No one has been careful to see that the fillings were smooth and polished so that they would not retain food. Nor have they been taught the necessity of brushing their gums or been advised as to how the mouth should be properly taken care of. So it is the duty of the hygienist to be kind in her criticism to these patients, and it will be found that the great majority of them will be only too glad to reform and faithfully follow instructions when they are once enlightened. The dental hygienists are to be the educators, to spread the gospel of cleanliness, and to aid both children and adults to keep well. Many times mouths will be found that are not as they should be; some may be quite shocking in fact, but it must be remembered that the chief mission is to treat and help others to know how to keep well, and after these unsanitary mouths have been seen to grow and develop into healthy ones under prophylactic skill and instruction, it will be realized that the service of the hygienist to humanity is a very important one.

Analyze one of these unsanitary mouths and study the conditions that are present. If the mouth contains alloy fillings the surfaces should be examined and also the margins of the fillings to see if they are rough. If so, the dentist must carefully grind and polish them in order that the results which may be expected from prophylaxis may be secured. If these alloy fillings are in the approximal surfaces of the teeth and the space between them is sufficiently large to permit the food to be squeezed down between the teeth and to injure or inflame the gum tissue, then the dentist should aid the hygienist by removing these fillings and replacing them with smoothly finished ones having proper contact points that will prevent the food from getting between the teeth. If there are gold crowns or banded crowns that do not fit tightly to the tooth or root and that will permit the end of the explorer to pass up between the root and the band or crown, it may be taken for granted that such a space is filled with decomposing food and is an ideal haven for bacteria. The odor arising from such crowns after their removal makes one realize the necessity for tight-fitting bands and flush joint operations. Hygienists will come to loathe the average gold crown and will use their influence against their insertion. Many of them are sources of systemic infection and nearly all will destroy the peridental membrane around the tooth, and result in the eventual loss of the tooth. Such dentistry is a serious menace to public health and has undoubtedly been the cause of many severe illnesses that have resulted even in death. If an ill-fitting gold crown is placed over a tooth containing a live pulp, it is but a question of time when the bacteria and the poisons generated by the decomposing process of the food débris lodging in the space under the crowns where the cement has disintegrated and washed away, will penetrate the dentin and infect and destroy the pulp. Alveolar abscesses from teeth carrying gold crowns are common. It would be far better for the patient who could not afford to have the work done properly, to have such teeth extracted. Ill-fitting bridges so constructed that it is impossible to properly remove the food with the brush and washes, will badly hamper work for mouth hygiene.

It is not necessary to know the details of the work of construction of crowns or bridges or of fillings, but it is necessary to know what constitutes good dentistry and sanitary construction. A small pimple on the gum, termed by the layman gum-boil, is in reality a fistula opening from an alveolar abscess. The attention of the dentist should be called to these fistulæ so that he may open the root canals and cure the abscess.

The gum tissue should now be examined. The term congested gums is applied to enlarged capillaries, engorged with blood and having a sluggish circulation. External irritation from lack of use and function in the mastication of proper foods is usually the cause for this congestion. The deep red color is due chiefly to the sluggish flow of blood laden with carbon dioxid. Perfect metabolism is not taking place in the cells of this tissue and the waste products are not being carried away with sufficient rapidity. Any local irritant on the surface or border of the gums will produce this congestion, and the mouths are rare that do not contain a number of congested surfaces.

In children this condition is produced chiefly by the sharp edges of decayed or broken-down teeth, temporary and permanent, and sufficient blood and serum ooze from these blood-engorged surfaces to form an excellent culture medium for pathogenic bacteria. The protruding edges of poorly made alloy fillings and abscessed roots of temporary teeth are common causes for these red and bleeding surfaces.

Every organism has its vulnerable or vital area which if sufficiently injured will eventually cause its death. The tooth is no exception to this rule. Its vulnerable point is the border of the peridental membrane directly beneath the gingival margin of the gum around the neck of the tooth, and this must be carefully safeguarded. This membrane forms the most vital part of the foundational structure of the tooth. Upon its health and resistance depend the function and life of the whole tooth. If it becomes injured, irritated or infected at its border and the lesion or infection is neglected, the membrane dies at this point, and in dying it causes the death and absorption of a similar area of the alveolar process which was in apposition to the affected membrane. This means a space or so-called pocket under the margin of the gum where food débris can find lodgement and where bacteria, well out of the currents of the saliva which flow freely around the teeth, can hold a tenable position.

The rapidity of the progress of death and absorption is dependent upon the resistant force contained within the cells of the membrane and upon the virulency of the attacking microörganisms. In childhood this membrane is thick and highly vascular and can resist almost any invasion of bacteria even when wounded, if not too seriously. In adult life it gradually becomes thinner, its blood supply is lessened, and as age advances the cells lose the high resistant force that they possessed in youth; and if the person is in what we call a run-down condition physically, from improper feeding of the body, unclean environments, harmful habits, excesses, or from any cause that will disturb the proper metabolism of the tissue by disturbing the nutritive or the nervous systems, the resistant force is still further lowered and the peridental membrane and the surrounding supporting tissues of the tooth become easy prey to the invading bacterial host. Although it will be possible to raise the resistance of this membrane again by prophylactic treatment and training of the patient in the proper methods of artificial stimulation, it can readily be seen that it is far more desirable to prevent the original disturbance at the neck of the tooth and save the patient the surgical treatment necessary in the hands of the dentist in order to get control of this much-dreaded and serious condition of absorption and infection of the supporting tissues of the root of the tooth. It must always be borne in mind that the most important part of the tooth is the root and any irritation of the gingival border of the gum, especially in adult life, is a menace to that tooth which is in closest proximity to the point of irritation.

PRACTICAL WORK.

In considering the practical work of dental prophylaxis the operation in the mouth of the adult will be first described, for as a rule the children do not need much instrumentation and their cases are therefore more simple.

In examining the mouth of a new patient regarding the gum tissue and the surfaces of the teeth, the hygienist should make sure that the patient has removed all of the food débris from the teeth that it is possible to remove with the tooth-brush, floss silk and mouth wash. It is never the duty of the hygienist to operate in a mouth that contains food débris. For her own self-respect and for the dignity of her calling, she should make it an absolute rule never to start an operation of prophylaxis when the patient has failed to clean his teeth of food débris before coming to her department. It is never her duty to remove food débris excepting the small quantities that roughened surfaces have made it impossible for the patient to remove. These cases will require some diplomacy on her part, for she must realize that the patient has not intentionally insulted her by presenting such an unclean mouth. It is merely that he has never been taught better. For years dentists have consented without remonstrance to operate in the mouths from which the food has not been removed from between the teeth, and it will be one of the missions of the hygienist toward the uplift of the dental profession to teach the public that they must not present themselves for any dental service whatsoever unless their teeth have been thoroughly brushed and flossed. She should be kind and considerate in the handling of such cases, and tell the patient that there is danger of infecting the gum tissues if the instruments are used around the necks of the teeth where there is decomposing food, and that, in order to obviate any such danger it will be necessary for him to step to the bowl and thoroughly brush and rinse his teeth before the operation.

A stock of tooth-brushes should be a part of the equipment of every dental office and should be charged up against the expense of dental supplies. The fifteen or sixteen cents the brushes cost, if bought in quantities, amounts to but little when we consider their absolute necessity for instruction, and their use when needed under these conditions.

Patients soon learn the rules of an office and in a comparatively short time it will be a rare thing to be obliged to send a patient to the bowl to brush his teeth before the prophylactic treatment can be started. Much of the soreness of the gums after these treatments in the mouths of new patients is due to crowding some of this infected material under the gum margin with the instrument, and it follows that the cleaner the necks of the teeth are before instrumentation, the quicker will be the recovery of the congested gums after treatment. With a pledget of cotton soaked with peroxide of hydrogen, the necks of the teeth and also the approximal surfaces should be bathed. The boiling of the peroxide will mechanically aid in loosening minute particles of food débris. After rinsing the mouth with warm water the teeth should be thoroughly sprayed on all their surfaces with compressed air and an atomizer. The air pressure should be at least twenty-five pounds, so that it may have enough force to blow the spray with sufficient speed between the teeth to aid in this mechanical cleansing. It makes no difference what liquid is used in the atomizer if it is harmless and has a pleasant taste.

Surfaces of the Teeth.—It must be remembered that in this work hygienists are not to cross the border-line into surgery. The laws in all States prohibit surgical or medicinal treatment by any but graduate practitioners. Therefore the entire efforts of the hygienist are to be confined to the exposed surfaces of the teeth and the area directly under the free margin of the gum.

The base of the crown of each tooth has four lines or boundaries. This is the entire field for the use of the instruments unless a root surface is exposed. It can be readily appreciated what a slow and painstaking piece of work it is to go over carefully each of these surfaces and remove all of the deposits of tartar. In the first treatments of neglected mouths the deposits are likely to be large and are usually found on all the surfaces at the necks of the teeth. It is impossible to remove all of these deposits at one sitting without subjecting the patient to an unnecessary strain. The large deposits may be broken down and scaled off and many of the smaller nodules can be removed, but it is quite impossible to be really thorough in the first treatment. Again, it is unwise to subject the patient to a too strenuous session, for if they are timid, they are apt to become discouraged by the long and tedious sitting. It is far better to arrange two sittings of an hour and a quarter to an hour and a half each than one of two hours and a half. If the appointment is made for two hours, the balance of the time may be spent in polishing and in instruction of the home care of the mouth.

The subject of calcareous deposits has been so thoroughly covered by Dr. Kirk, that it is unnecessary to go into the subject very deeply, but attention should be called to the irritating action they display in their porousness in absorbing liquefied débris, therefore forming an excellent retainer for bacteria. It is absolutely essential for the health of the gums and the roots of the teeth that all such deposits be removed at frequent periods. The time may come when people may be induced to eat the proper foods in proper quantities, then this deposit will be greatly lessened, but until this goal of good sense is gradually reached, artificial care of the mouth by prophylactic treatments will have to be resorted to.

Much of the evil from the forming of serumal deposits in the subgingival space can be obviated by eliminating the congested condition of the capillary circulation found in the gum tissue of the mouth of the average adult. But the mouths are indeed rare in which no new deposits can be found under the gingival border after a period of two months.

System for Instrumentation.—In order to perform a prophylactic operation intelligently one must must work by system, and the instrumentation as well as the polishing must have a definite starting-point in the mouth and should always proceed in the same given direction over the surfaces of the teeth in the case of every patient. This is necessary for thoroughness and also in case of interruption, for if one will but note mentally the last tooth being worked upon before leaving the chair, the chain will remain unbroken upon resuming. It matters little what system is finally adopted, but the one here suggested will be advocated to start with.

Lower Jaw.—Beginning at the lingual surface of the last molar of the right side, lower jaw, at the gingival line, distolingual angle, instrumentation proceeds mesially until the lingual border of the left lower central is reached. The same direction is now followed but the

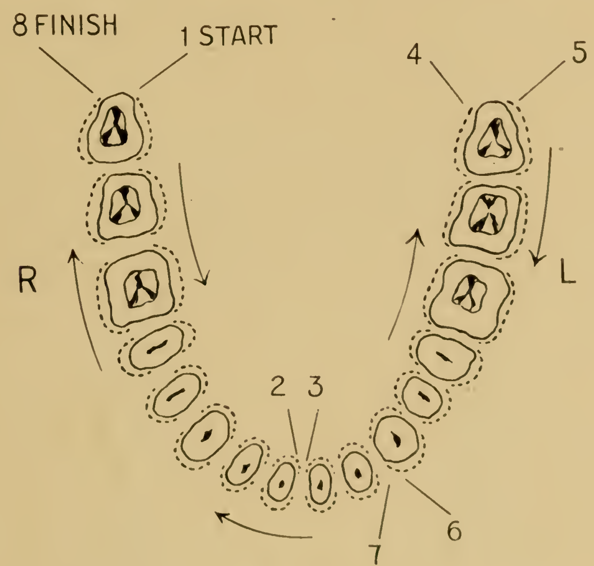

Fig. 125

line of operation becomes distal on the left side, still keeping on the lingual surface until the distolingual angle of the left lower last molar is reached.

Again starting on the distobuccal angle of the left lower last molar, the instrumentation proceeds bucally and mesially until the left lateral is reached, where from this point the operation continues on the same surface to the distobuccal angle of the right lower last molar.

The following cuts are taken from Plate VI of the *American System of Dentistry*, and will, by the dotted lines and arrows, better illustrate the directions followed as just described. Fig. 125 represents the teeth of the lower jaw with crowns excised at the gingival border. These cuts will illustrate the lines to be followed and field of operation to be covered by the dental hygienist with the instruments.

As shown by the dotted lines in Fig. 125, this first use of the instruments on the lower teeth covers only the lingual and buccal surfaces. By working along on the same surfaces of the teeth on the same jaw, considerable time may be saved by not having to change instruments every moment or two, as one instrument frequently will adapt itself to eight teeth before it will be found necessary to change.

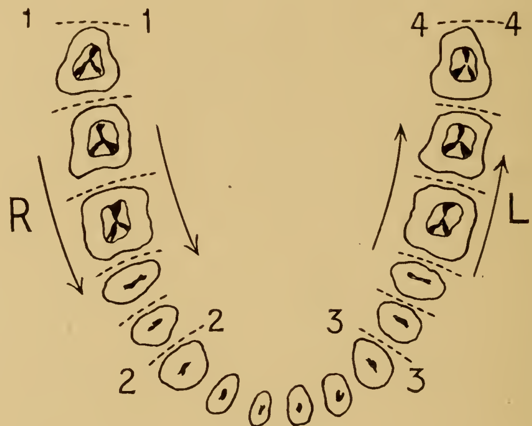

Fig. 126

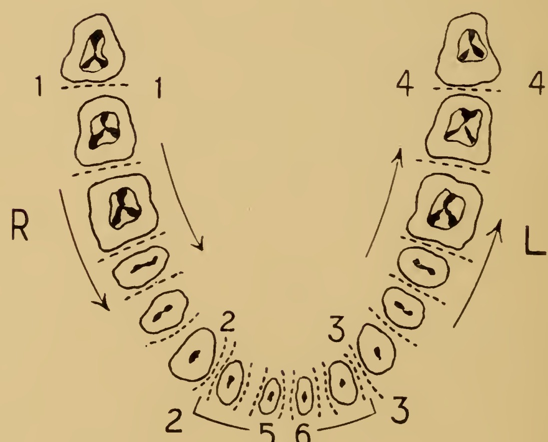

Fig. 127

After the deposits have been removed from the lingual and buccal surfaces, attention is given to the distal surfaces. Once more beginning on the distal surface of the right lower third molar, the distal surface of the right lower molars, bicuspids and cuspid are carefully scraped. Next the distal surfaces of the left lower cuspid, bicuspids and molars, as illustrated in Fig. 126. One instrument will usually adapt itself to these surfaces. Next the mesial surfaces of the right lower molars, bicuspids and cuspid, then the mesial surfaces of the left lower cuspid, bicuspids and molars. These surfaces, too, may usually be covered with one instrument. Lastly, the approximal surfaces of the lower incisors, which may be covered with two instruments (Fig. 127).

Upper Jaw.—On the upper jaw at the point corresponding with that where work was first started on the lower jaw, the distolingual angle of the right upper third molar, the lingual surfaces of the superior set are cleaned of all calcareous deposits, working mesially until the left central is reached, then distally to the left third molar. Again starting at the distobuccal angle of the right upper third molar the buccal

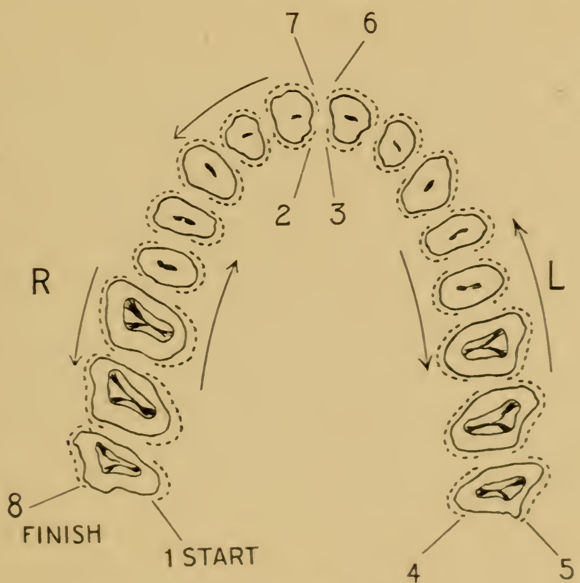

Fig. 128

surfaces are gone over, working mesially to the left central then distally to the right third molar (Fig. 128). Now beginning at the right third molar, the distal surfaces of the right molars, bicuspids and cuspid are scraped. Next the distal surfaces of the left cuspid, bicuspids and molars (Fig. 129). In the same order the mesial surfaces are gone over, leaving the approximal surfaces of lateral and centrals until the last (Fig. 130).

If this briefly outlined system is followed there will be but little chance that the deposits may escape the play of the instruments.

There is nothing that instills a greater confidence in the operator, in the mind of the patient, than the gentle touch of his hand and the instruments. The very first requisite is to try to develop a firm yet gentle touch. In handling the lips, the cheek, the tongue, the motions should be slow enough and deliberate enough to insure gentleness. Such precautions in self-training soon improve the technic in hand-

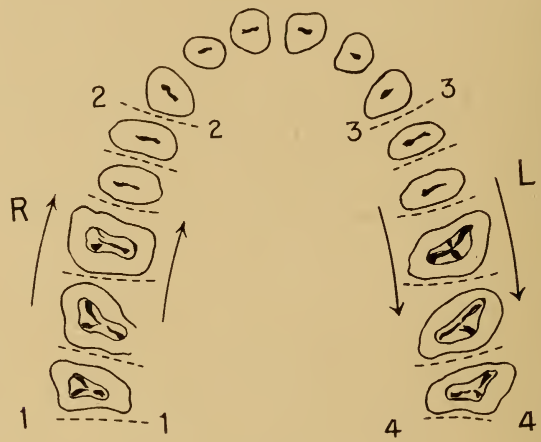

Fig. 129

ling the instruments, and it is much the better fault to be over-gentle and a little less thorough to begin with than to be heavy-handed, rough and overstrenuous with the instruments. There is no better application of the golden rule than in dentistry, and the operator

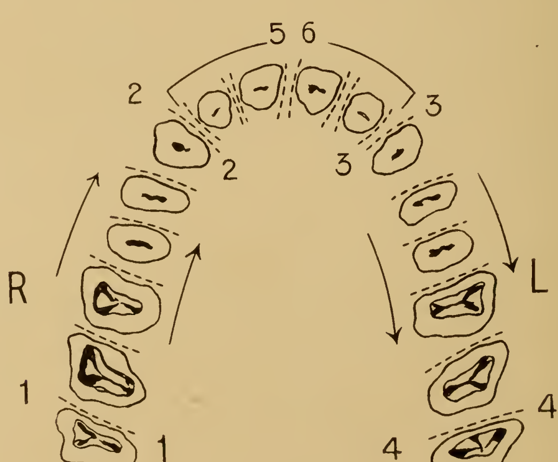

Fig. 130

who masters a fine sense of touch and constantly keeps in mind a sympathetic consideration for his patient, has conquered much that is productive of success.

One of the most perplexing and yet one of the most essential things to master at the start is the proper handling and use of the mouth mirror. The mouth mirror is especially essential in operating on the lingual surfaces of the upper teeth and can also be used to advantage in holding the tongue away from the lingual surfaces of the lower teeth.

As the motion reflected in the mirror is reversed from that of direct observation, it is puzzling at first to place the instrument properly, but a little practice will soon obviate the difficulty. The Dunn cheek distender is used to expose the buccal surfaces of the teeth, both in instrumentation and polishing, and its use adds much to ease of vision and access to these surfaces.

The Four Motions.—In instrumentation, as well as in polishing, there are four distinct motions. These may be termed digital, wrist, rotary

Fig. 131

or forearm and rigid arm. In acquiring these movements the fulcrum point of the hand in relation to the hold of the instrument is the determining factor. If the digital motion is to be used, the instrument or polisher is grasped as illustrated in Fig. 131. The end of the right thumb is the fulcrum-point or rest. This position permits of a perfect control of the instrument and allows a play of the instrument in either a push or a pull stroke. This motion is used particularly on the teeth of the upper jaw. It might be well to state here that no instrument should be used in the mouth unless the hand is first braced by a suitable rest for one or more of the fingers of the hand holding the instrument. No free-hand motion should be used. Such motions would be almost sure to invite a slip of the instrument and result in laceration of the gum tissue. The wrist motion is acquired by holding the instrument as illustrated in Fig. 132, using the end of the second or third fingers as a fulcrum. This motion may be used in various parts of the mouth, especially on the lingual surfaces of the molars and bicuspids, but it is not as effective for general use as the forearm or rotary movements. The forearm or rotary motion is used on both the upper and lower jaws and usually the end of the third finger serves as fulcrum, although that of the second finger can sometimes be used. This motion is produced by holding the muscles quite rigid, allowing the rotation of the radius around the ulna bone of the forearm to play back and forth in a limited area. After a little practice this motion permits of a rapidity of work with the instrument under perfect control, and to master this stroke is to master much of the technic of instrumentation and polishing.

Fig. 132

Fig. 133 illustrates the position of the hand when using the rotary motion.

The rigid-arm motion is used for polishing nearly all of the labial and buccal surfaces of the teeth, both upper and lower, and for the lingual surfaces of the molars and bicuspids. The rest is usually found by using the side of the second joint of the right thumb on the chin or the second joint of the third or fourth finger as illustrated in Fig. 134.

The muscles of the whole arm are made fairly tense and the arm is made to travel forward and backward in a short, limited area. All of these motions should be practised over and over again on manikins or on natural teeth set in modeling compound before being tried in the mouth. They are not easy to master and the muscles must be trained by repeated practise.

In the removal of tartar around the necks of the teeth, there are two strokes that may be utilized, a push stroke and a pull stroke. Which to use is determined in a great measure upon the quantity or bulk of the deposit and also upon the tenacity with which it may cling

Fig. 133

to the tooth surface. In scaling off pieces of hard deposits, large or small, the draw or pull stroke will be found most effective. The instrument is carefully carried a little below the gingival border of the gum and hooked securely over the shoulder of the deposit. Then with the

Fig. 134

hand properly braced, the instrument is firmly drawn toward the masticating surface or cutting edge of the tooth—a second digital motion. When the deposits are small and fairly soft, a short, pushing stroke will be more effective.

5 6 18 17

Fig. 135

13 14 3

Fig. 136

Instruments.—Before the handling of the instruments is described in detail a set of scalers will be considered that should be sufficient for the beginner for all prophylactic work upon the necks and crowns of the teeth. These include nine instruments and may be described as follows:

Fig. 135. The two small curved instruments with the spoon-like ends are known as Nos. 17 and 18 of the set of Darby-Perry excavators. They are curved in opposite directions to each other and are paired as rights and lefts. Dr. C. W. Strang, of Bridgeport, Ct., suggested their use. Nos. 6 and 7 belong to the D. D. Smith set and are made by J. W. Ivory, of Philadelphia. Fig. 136, Nos. 13 and 14 were designed by Dr. E. S. Gaylord, of New Haven, Ct., and are a

3 4

Fig. 137

part of the Smith set. They are also made by J. W. Ivory. No. 3 sickle-shaped instrument is made by the S. S. White Company, and is used for the removal of heavy deposits by the pull or digital stroke. Fig. 137 illustrates Nos. 3 and 4 from the Harlan set of scalers made by the S. S. White Company.

INSTRUMENTATION.

Lower Jaw.—Assuming that the deposits are not unusual in quantity and are reasonably easy to remove, the adaptation of these instruments will be described, proceeding as in Fig. 125.

Starting at the distolingual angle of the last lower right molar, No. 18 of the Darby-Perry excavators is selected and held at an angle, as shown in Fig. 138. The stroke used is a short downward push, and a wrist motion is used with the blade held at nearly a right angle with the tooth. On the downward stroke, the back of the blade with its smooth, blunt surface will strike the gingival border of the gum and prevent the cutting edge of the instrument from traveling far enough to injure the peridental ligament. This short stroke is rapidly repeated, the operator making a wave-like motion of the instrument, gradually moving it forward, mesially, on the lingual surface of the molar until the mesiolingual angle is turned, and using the mouth mirror with the left hand to keep the tongue out of the way. The instrument is now transferred to the next molar and the operation is repeated. This

Fig. 138

is continued with the same instrument until the left lower central is reached, from No. 1 to No. 2 in Fig. 125. The mate to this instrument, No. 17, is now substituted and the operator, starting on the lingual surface of the left central, Fig. 139, and using a rotary stroke, continues until the distolingual angle of the left lower last molar is reached, Fig. 140 or from No. 3 to No. 4 in Fig. 125. These small instruments greatly magnify the sense of touch, so that each small deposit is readily felt, whereas a larger instrument might pass it by.

Again starting at the distobuccal angle of the left last molar with instrument No. 18, Fig. 141, this short, pushing stroke with a wrist motion is used until the left lateral is reached. From No. 5 to No. 6 in Fig. 125. Although the same instrument can be used effectively on the labial surfaces of the incisors, it will be found advantageous to change for its mate, No. 17, and, leaning slightly in front of the

Fig. 139

Fig. 140

patient, brace the hand by the third finger on the masticating surface of the first bicuspid (Fig. 142), using a wrist motion which permits

Fig. 141

Fig. 142

of a careful handling of the festoons of the lower incisors. After the labial surface of the left lateral is finished, the hand is moved forward to engage the next tooth. At the right cuspid the rotary stroke is now adopted and continued to the last molar. Fig. 143 or from No. 7 to No. 8 in Fig. 125. The finger rests for the work just described are found on the masticating surfaces of the bicuspids or on the cutting edge of the cuspids or incisors.

The base of each tooth has four lines. Two of these lines have now been covered, and there remains the approximal surfaces or the distal and mesial lines. No. 13 is an instrument with the end bent at an

Fig. 143

angle of forty-five degrees, having a long blade with a file-cut surface, the numerous small blades of which are very effective in removing the small deposits. This instrument should be used chiefly with a pull stroke, starting at No. 1, in Fig. 126, which is the distal surface of the right lower last molar, as shown in Fig. 144. The distal surface of the last molar being free, the blade is carefully passed down under the gum line until the sense of touch determines the bottom of the subgingival space. The blade is then brought tight against the tooth surface and pulled upward. An eighth to a quarter of an inch play of the blade is sufficient to dislodge the deposits. This stroke is rapidly repeated across the back of the tooth. In adapting this instrument to the distal surface of the second molar the blade is inserted

Fig. 144

Fig. 145

sidewise from the buccal surface (Fig. 145), and with a short push-and-pull stroke the instrument is worked between the teeth in order to cover the entire distal line. If the teeth are so shaped and are so close together that they will not permit the blade to pass between them, then the instrument should be inserted also from the lingual surface

Fig. 146

and in this way that part of the distal line that was inaccessible from the buccal surface is covered. With the same instrument the distal surfaces of the teeth may be scaled to the incisors, or from No. 1 to No. 2, in Fig. 126. Again, with the same instrument, the operator should start

Fig. 147

on the distal surface of the left cuspid, and entering from the buccal side, proceed on to the last molar, or from No. 3 to No. 4, in Fig. 126. The procedure for the mesial surfaces is the same as described for the distal, except that the instrument used is No. 14, and one position is illustrated as in Fig. 146. Both push and pull strokes are employed. The lower incisors are scaled on their approximal surfaces by the bayonet-shaped Smith scalers, Nos. 6 and 7, from No. 5 to No. 6 of Fig. 127, which shows this area. Fig. 147 illustrates the adaptation of these instruments.

Upper Jaw.—On the upper jaw, at the right distolingual angle of the last molar, instrument No. 17 is placed at nearly a right angle with the tooth and, with the hand braced on the top of the left lower lateral and cuspid teeth, using the third finger as fulcrum (Fig. 148), a wrist and digital motion is employed, the instrument being made to travel forward with a short up-and-down, push-and-pull stroke combined, perhaps better described as a waving stroke. The fulcrum-point is maintained, the instrument being drawn in or shortened as the incisors are approached. When the left central is reached (Fig. 128),

Fig. 148

instrument No. 18 is substituted, the second finger used as a fulcrum on the cutting edge of the right upper cuspid (Fig. 149), and the lingual surfaces of the upper teeth of the left side are gone over with a wrist and digital motion. This fulcrum-point is maintained and the instrument advanced in length with the thumb and first finger (Fig. 150). Again starting at the distobuccal angle of the left upper third molar, the third finger is placed slightly back of the cutting edge of the right upper lateral and central while the second finger rests on the cutting edge of the left upper central (Fig. 151). This position can be held until the left lateral is reached, the motion being wrist and digital. Shifting the fulcrum-point to the end of the third finger on the edge of the right upper cuspid, the labial surfaces of the left central and lateral may be scaled with the same instrument. With the hand resting against the chin just below the lower lip, and the third joint of the little finger serving as a fulcrum, with instrument No. 18, the right central and from there back to and including the third molar is scaled, using the digital motion, as in Fig. 152.

The lingual as well as the labial and buccal surfaces, having been covered, No. 13 is used for the distal surfaces (Fig. 129) of all the upper teeth excepting the incisors. For the molars, bicuspids and cuspids of the upper jaw the description of the use of this instrument for those on the lower jaw may be applied, the hand rest being found chiefly on the cutting edge of the lower incisors, the end of the third finger

Fig. 149

serving for fulcrum. No. 14, Fig. 153, is used in a similar manner with the hand rests the same as for No. 13. Nos. 5. and 6 are best adapted for the approximal surfaces of the incisors, their use at this point being too self-evident to need explanation.

Even with this detailed description, much will be found lacking to the beginner, but after a little prastice on the manikin the hand will soon adjust itself to the proper rests to secure the greatest efficiency and control of the instrument.

In removing the heavy deposits the sickle-shaped instrument, No. 3, will be found most useful. In skilful hands it is possible to scale

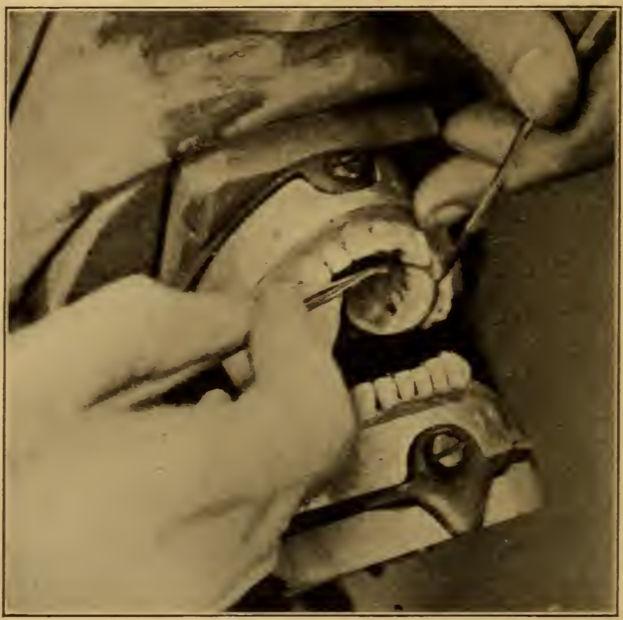

Fig. 150

Fig. 151

roughly nearly all the surfaces of all the teeth with this one instrument, the exception being approximal surfaces. It is used with a draw or

FIG. 152

FIG. 153

pull stroke and has the advantage of not being dangerous around the anterior teeth, for the point of the instrument as well as the side of the blade is inserted under the deposit and pulled directly upward on the lower teeth and downward on the upper teeth. But in the back of the mouth where its adaptation necessitates the drawing of the instrument forward under the border of the gingiva, the point is likely to slip and travel too deep into the subgingival space unless care is used. A firm hold on the instrument and a secure brace of the hand is absolutely essential. This sickle-shaped instrument is used almost entirely with a digital motion and the two principal positions are illustrated in Figs. 154 and 155. It is very difficult to scale the teeth thoroughly with this instrument, but the larger deposits having been removed at the first sitting, Nos. 17 and 18 can be used to advantage at the second and all subsequent treatments.

The Harlan instruments, Nos. 3 and 4, are also used with a draw stroke and are helpful in removing the small, hard, tenacious deposits under the free margin of the gums. They are adaptable in nearly all sections of the mouth and their use is usually self-suggestive. When these small deposits resist Nos. 17 and 18, especially on the bicuspids, cuspids and incisors, these Harlan instruments will be found very effective.

If uncertainty exists in the mind regarding the thorough removal of all deposits, an instrument known as an explorer carefully passed around the neck of the tooth under the gingivæ will readily detect any small deposits or uneven surfaces. The smaller the instrument, the more greatly is the sense of touch magnified. It is for this reason that the use of Nos. 17 and 18 is advised wherever practical.

There are two special features to be considered under instrumentation. First, the sensitiveness that is frequently found around the necks of the teeth, and second, the bleeding of the gingival borders of the gums. In adults where the lime deposits have been heavy, their removal will frequently cause much sensitiveness for a week or two, sometimes even longer, to heat and cold and to sweets and acids. The deposits have caused an absorption of the border of the alveolar process and the soft tissues around the necks of the teeth, and when they are removed a portion of the cementum is exposed which later disappears and exposes the interglobular spaces on the border between the dentin and the cementum, forming an area that is highly sensitive to the touch of the instrument or polisher. It is frequently wise to inform the patient that he may expect the surfaces to be responsive to heat and cold for a short time, in order to allay any fears on his part. The deposits acting as a covering for these surfaces have protected them from external irritation, and the patients are apt to wonder why it is that their mouths are so much more sensitive than they were before the deposits were removed. Acids are especially irritating to these surfaces and the use of bicarbonate of soda, half a teaspoonful to a third of a glass of warm water, used as a mouth wash two or three times daily, will aid greatly in tiding over this short period of discomfort. If the soda can be used clear by dipping the finger in water,

Fig. 154

Fig. 155

touching it to the soda and then rubbing it on these surfaces, it will all the more quickly neutralize any acid that may be irritating to this sensitive tissue. The thorough rubbing and polishing with the stick and pumice and the extreme cleanliness from the faithful use of the tooth-brush will soon bring these troublesome areas under control. A 10 per cent. solution of nitrate of silver is sometimes advised, but if it is used, it should be followed by a thorough polishing with the stick and pumice.

The second feature, which will be considered briefly, is the bleeding of the gums during instrumentation. When the gums readily bleed there is congestion of the capillaries, and the more blood allowed to escape from the gingivæ, the sooner the congestion will be relieved. Instead of trying not to make the gums bleed, just the reverse course should be followed, although of course this does not mean that they should be lacerated or the tissue wounded. The bleeding process is produced by using the back or smooth surface of the blade of the instrument with pressure, and this is done while removing the lime deposits, and if there is a copious flow of blood from some of the approximal surfaces, it should be encouraged by rapid, gentle pressure strokes directly on the gingivæ. Healthy gums will not bleed during instrumentation, and when bleeding occurs enlarged and congested capillaries are sure to be found. No fear of causing injury to the gum tissue in causing a flow of blood need be felt as long as care is taken that the blade of the instrument does not cut the tissue. Frequently after such a treatment the gums will take on a color two shades lighter before the patient leaves the chair, and after a few days of stimulation with the tooth-brush it will be hard to recognize it as the deep red, congested tissue that it was at first.

POLISHING.

It is impossible to obtain the same results in prophylaxis with the use of the dental engine in polishing as may be secured with the hand polishers. This belief is based upon personal experience in faithfully trying out both methods, and is an accepted fact by all prophylactic workers who have become proficient with the hand polishers.

The object of this polishing process is threefold. First, the removal of stains, placques and films or all soft accretions on the exposed surfaces of the teeth. Second, a polishing of the enamel surfaces and a stimulating effect that seems to be imparted to the living tissue of the tooth itself by the vigorous massage. Third, the beneficial results obtained on the gingival borders of the gums by the slight bumping of the stick, causing light pressure and release which imparts a massage effect and aids greatly in producing a perfect flow of blood through the capillaries in the peripheral circulation. If a new case presents itself in which the teeth are very badly stained, it is perfectly reasonable, if desired, to use the dental engine for the first treatment to aid in cleaning off these stains from the enamel surfaces, but all subsequent treatments should be made with the hand polishers. An engine revolving at six or eight hundred revolutions a minute, with the rubber cup or buff charged with pumice, cuts too viciously and if used at each prophylactic treatment, will in time affect the enamel and tooth structure at the necks of the teeth. With the dental engine all sense of touch is lost, and besides it is not as adaptable on the approximal surfaces or on the surfaces of the molars as the stick held in the hand. The gingival borders of the gums, in many mouths, have been badly wounded or damaged by the revolving cups or buffs in the dental engine, and if one hopes and expects to secure the best results in obtaining ideal health conditions of these tissues, one must become proficient

Fig. 156

with the hand polishers. Those who would advocate the dental engine are those who have failed to make themselves proficient with the hand polishers. There can be no choice if the latter is faithfully tried. There are a number of different woods that may be used for polishing, as cedar, maple, hard pine, etc., but the closest-grained wood and the one best adapted for this purpose is orange wood. There are two sizes of sticks that may be had from the dental depots, known as large and small. The large size is cut about three quarters of an inch in length and one end is cut wedge-shaped. This stick is used on all the broad surfaces of the teeth excepting the masticating surfaces. The small stick is cut about the same length and one end is cut like the point of a lead-pencil. The smaller stick is used on the approximal surfaces and around the necks of the teeth where it is impossible to adapt the larger stick.

In order to work with facility, two holders for the two sizes of sticks should be employed. Fig. 156 illustrates the Jack porte polishers with sticks in position.

As a slight abrasive and polish to be used with the sticks, the finest grade of pumice moistened with water will prove to be the most satisfactory. Although other polishing mediums are used with good results, it is doubtful if there is anything superior to fine pumice for this special work. A scant spoonful placed in a small porcelain dish, and wet sufficiently with water to be almost liquid, will make a mixture that can readily be picked up on the point of the wet stick and used in the mouth.

System for Polishing.—Just as a definite system is employed in going over the teeth with the instruments, so should a system for reaching all surfaces of the teeth with the polishers be followed.

Fig. 157

The following system is very effective and its adoption is suggested, at least for beginners:

Starting on the labial surface of the right upper central with the large stick, the polishing progresses backward to the right lateral, then to the right cuspid and so on until the right last molar is reached. From this point start on the buccal surface of the right lower last molar and progress forward around the buccal and labial surfaces of all the lower teeth to the left lower last molar. Transferring the stick to the buccal surface of the left upper last molar, the polishing is continued forward to the median line to and including the left upper central. All the labial and buccal surfaces have now been polished with the use of only the larger stick. Fig. 157 illustrates direction for polishing. Then starting on the lingual surface of the right lower last molar with the large stick, the polishing of the lingual surfaces proceeds forward to the incisors, then backward, or distally, to the lingual surface of the left lower last molar. Again beginning on the lingual surface of the left upper last molar, all of the lingual surfaces are covered, ending on the right upper last molar.

So far only the large stick has been used. Now with the pointed stick the same course should be followed over the teeth as has just been described, polishing in between the teeth as far as possible and rubbing the necks of the teeth under the free border of the gingivæ, keeping the edges of the sticks sharp. When they become frayed or brush-like, they should be trimmed off with a pair of scissors, or if, after this, the edges are still too blunt, sharpened with a knife.

The polishing is confined almost entirely to two motions, the rigid-arm and the forearm or rotary. The one exception is the digital that should be used by beginners on the labial surfaces of the upper incisors.

Fig. 158

In order to polish effectively pressure must be used. It is this one point of being able to apply pressure on all the surfaces while polishing that makes the operation difficult. This is noted especially in polishing the lingual surfaces of the molars and bicuspids. The proper hand rests are essential and also muscular practise of the motions used for this work.

Beginning on the labial surface of the right upper central with the large stick, and using a digital motion, the stick is made to travel up and down the full length of the face of the tooth, rubbing the surface with both up and down strokes. The stick is allowed to bump the gum lightly but not hard enough to cause discomfort. Considerable pressure is used and the motion is rapid. Fig. 158 illustrates the position of the hand with the thumb rest on the cuspid for the digital motion. When the right cuspid is reached the rigid-arm motion is employed, with the back of the second finger, between the second and third joints, resting on the chin and the two bicuspids are rubbed and

Fig. 159

Fig. 160

polished up and down or longitudinally, the right thumb pressing on the polisher at the end of the stick (Fig. 159). Now inserting the Dunn cheek distender, the buccal surfaces of the molars are rubbed crosswise, using the rotary motion and the same fulcrum position that was used with the cuspid and bicuspid, but the porte polisher is shifted in the hand and grasped as one would hold a pen-holder (Fig. 160). The end of the stick may be made to travel up and down part way on the approximal surfaces, but the principal motion for polishing is crosswise. The polishing of the right lower molars is the same as described for the upper molars. For the right lower cuspids and bicuspids, the same as for the upper. The first finger of the left hand now is placed across the inside of the lip to depress it and with the polisher grasped in the fist with right thumb resting on the left forefinger (Fig. 161), the lower incisors are polished. For the left cuspid and bicuspids the same position as for the right is used. In polishing the left lower and upper molars the back of the third finger

Fig. 161

becomes the fulcrum on the side of the chin and the polisher is grasped pen-holder fashion, as in Fig. 162, using the rigid-arm motion. The descriptions of the right cuspid and bicuspids, lateral and central, will apply to the left. It will be noted that, with the exception of the upper incisors and right molars, the motion used on all the outer surfaces of the teeth has been rigid-arm. That on the inner surfaces of both lower and upper is forearm or rotary. The difficulty met with is that of producing pressure and at the same time retaining control and length of stroke. With the mouth mirror in the left hand to hold the tongue away, the back of the third and fourth fingers are pressed against the chin, and the polisher held as the pen-holder in a rigid grasp (Fig. 163), the stick is made to travel up and down on the inner surface of

Fig. 162

Fig 163

the right lower molars, the edge of the stick pointing up and down with the long axis of the tooth. This polishing motion, it will be noted, is just the reverse from that used on the buccal surfaces. By shorten-

Fig. 164

Fig. 165

ing the hold on the polisher the same position is used for polishing the bicuspids and cuspids.

Other adaptations of the stick will be found that are advantageous

Fig. 166

Fig. 167

for these surfaces, such as using the side of the stick with an up-and-down stroke instead of its sharpened end.

By leaning forward in front of the patient the second finger is placed on the top of the left cuspid or bicuspid and with a rocking or rotary

Fig. 168

Fig. 169

motion of the arm and stick the lower incisors are polished (Fig. 164). The left lower molars are polished with the same pen-holder grasp, using the second finger as a fulcrum on the right lower cuspid or lateral

(Fig. 165). The mouth mirror can be used to good advantage while polishing the lingual surfaces by having the patient sit low enough in the chair. Starting on the lingual surface of the left upper last molar, the porte polisher is held like the pen-holder and, with the end of the third finger resting on the labial surface of the right lower cuspid (Fig. 166), the molars are rubbed chiefly up and down with the edge of the stick. Holding the same fulcrum-point, the grasp on the polisher is gradually shortened and the incisors are polished as shown in Fig. 167. The lingual surfaces of the left cuspid, bicuspids and molars are polished with the same hold of the polisher, the rest being found on the chin, using the back of the second joint of the third finger (Fig. 168). The motion used is mostly forearm or rotary.

Fig. 170

All of the positions and fulcrum-points described for the large stick apply also to the small stick. The pointed stick is used between the teeth, rubbing the surfaces as far as the stick can reach and also around the necks of the teeth on all of the surfaces. Its use should start at the same point, the right upper central, and travel over the teeth with the same system as that described for the large stick. The points of both polishers should be kept trimmed with the scissors and when they become too blunt, sharpened with a knife. Where the gums between the teeth are congested, the side of the stick is pressed against them with a fast, quick stroke to encourage the bleeding. Care should be taken in the use of both sticks not to abrade the gingivæ, but the light pressure with the side of the stick against the gum margin will prove very beneficial (Fig. 169). When sensitive surfaces are found at the necks of the teeth, the pointed stick freely charged with pumice is applied with vigor and considerable pressure. A thorough polishing of their surfaces will greatly aid in reducing the sensitiveness.

Floss Polishing.—After polishing with the sticks there still remain the contact points and an area on the approximal surfaces that have not been reached. By doubling a length of ligating silk, twisting it and dipping it in water and then in pumice, these surfaces may be polished quite effectually. When the teeth are very close together a single strand will be found sufficient, as this silk is larger in size than that sold for every-day flossing. Cutters' wide floss may also be used to advantage where the space will permit. When using the floss for polishing it should be passed between the contact points with care,

FIG. 171

so that it will not snap on the gum, drawn back and forth on the distal surface of the tooth and then pressed backward rubbing the mesial surface of the adjoining tooth. Most of the decay takes place in these surfaces and they must be given careful attention. If the ends of the floss are wound around the first fingers as illustrated in Figs. 170 and 171, it can be easily manipulated.

Brush Wheel.—The masticating surfaces are so uneven that a stick cannot be used on them very well, so it will be necessary to use a brush wheel in the engine to reach down in the fissures to polish these surfaces. With the wheel dipped in water and the edge of it touched to wet pumice, the engine should be run at a moderate speed and the edge of the wheel applied down in the fissures of the molars and bicuspids. The Dunn cheek-distender should always be used. It is almost unnec-

Fig. 172

essary to state that the sticks, the pumice, the floss and the brush wheel should not be used a second time. Figs. 172 and 173 show the adaptation of this wheel.

Fig. 173

Children.—In the prophylactic treatment of children it is seldom necessary to use the instruments. As it is the roots of the teeth that are most susceptible to disease in adults, so are the approximal surfaces most susceptible in children. These surfaces should be carefully polished with the floss and pumice, and the fissures in the masticating surfaces with the brush wheel in the engine. The polishing of all the surfaces of the teeth with the sticks should be done as described for the adult. In order to assist in the removal of the green stains on the surfaces of the teeth at the first treatment a small napkin may be used to dry the teeth, and a pledget of cotton soaked with Churchill's compound tincture of iodin applied to the stains and allowed to penetrate them. It is sometimes necessary to make a second application of the iodin after the first thorough polishing, but after the teeth have been thoroughly polished and the patient is coming at regular intervals for these surface treatments, no further use of the iodin will be necessary. Attention is called to a preventive treatment of the fissures in the first permanent molars of children that comes within the province of the dental hygienist.

When these fissures are found to be exceptionally deep, likely to retain food débris and thus susceptible to decay, a quick-setting, hydraulic cement should be mixed, and with cotton rolls on each side of the tooth, the fissures should be dried with warm air, and washed with a pledget of cotton soaked with alcohol, again dried and then with an explorer the soft cement worked down into the fissures. As the cement begins to toughen and set, the end of the second finger is dipped in a glass of water and with the ball of the finger the cement is pressed firmly down into the fissure and held there for a moment or two until it has become fairly hard. The surplus can easily be trimmed away and the cement in the fissures will last for some time, acting as a protection to their surfaces. It takes but a short time to renew it when it wears away, and will frequently save these teeth from decay at the susceptible period of from six to twelve years of age.

BRUSHING.

Because a remarkable condition of health and beauty of the gums and a high resistance and increased vitality of the peridental membrane may be developed by the proper form of brushing, it may be well to consider first the blood supply to the peridental membrane and how its vitality may be greatly increased by establishing fast and perfect circulation in the gum tissue itself.

Plate VII illustrates, diagramatically, the blood supply to the peridental membrane of a tooth. The small arteries entering the apical space break up into branches, one or more of them enter the pulp canal through the apex of the root, and the others pass down between the fibers of the peridental membrane. During their course through the membrane on their way to the alveolar border and the gum tissue they both give off and receive branches through the alveolus and connect with the plexus of small bloodvessels and capillaries of the gum tissue.

It will thus be readily seen that the blood circulation in the gums is very intimately associated with the peridental membrane. It frequently happens that when an alveolar abscess develops at the apex of the root of a tooth, these bloodvessels in the apical space are destroyed, yet the peridental membrane does not suffer from lack of blood, for the branches coming to it from the walls of the alveolus soon enlarge and produce a sufficient supply. It must therefore be noted that in order to stimulate the blood supply of the peridental membrane it is merely necessary to stimulate circulation in the gum tissue. Fibers of the peridental membrane radiate out into the gum tissue and strong bands of fibers which form the dental ligament blend into the periosteum of the alveolar process. Because some of these fibers are so close to the surface in the gum tissue it is not difficult to understand why an unusual response to health may be obtained by surface stimulation.

In the process of masticating coarse foods a natural massage takes place in the following manner: The teeth, being occluded with considerable force, are pressed down in their sockets. The peridental membrane is thus compressed and the blood is squeezed out of the small bloodvessels. As the jaws open and release the pressure on the teeth, the pressure on the small bloodvessels in the membrane is also released and the blood comes rushing in again.

This pressure and release is similar in its action to a massage of the tissues on the surface of the body. The coarse foods sliding over the surfaces of the teeth press upward on the upper gums and downward on the lower gums. This pressure and release on the bloodvessels in the gum tissue acts in the same manner as that on the peridental membrane. Such a process always stimulates a free flow of blood and prevents congestion or stasis in the capillary circulation.

Keratin.—In the basement layer of the skin, cells are constantly being formed and forced slowly upward toward the surface of the body. During their transit the cells slowly change their shape, becoming long and flat in appearance and finally form the pavement or squamous type of epithelum on the surface of the skin. During this period, from the time of formation to their arrival on the surface of the body, a gradual metamorphosis or change takes place in the protoplasm of the cell. Slowly the contents of the cell begins to toughen and this process continues just in proportion to the needs of protection against undue friction or exposure. The horny hands of the day laborer, or the corns that form on the feet, are examples of the extreme expression of the activity and change in these cells. The contents of the cells when so changed or toughened is known as keratin.

The mucous membrane of the mouth is but a continuation or an infolding of the skin. Its epithelium is of the squamous type similar to that of the skin. If the gum tissue is artificially stimulated three or four times a day with the bristles of the tooth-brush, a noticeable change takes place in the texture of the mucous membrane. It soon loses that smooth, glassy or slazy appearance and under a magnifying glass shows a thickened or toughened surface which seems to act as a protective armor for the underlying tissues and makes the ingress of infection through the gum tissue, or at the gingivæ, extremely difficult. Inference should not be made that there is produced a hornified mucous membrane, except in a modified sense, but a beneficial change takes place that is much to be desired. A similar texture of membrane may be found in the mouths of carnivorous animals.

The Gums.—In considering the health of these dentinal tissues the gums found in the average mouth should first be noted. Aside from the unsanitary aspect of the crowns of the teeth, the gums will be found to be of a deep red color, the gingivæ usually showing even a deeper red. The blood is almost stagnant on some of the margins, and the tissues will bleed upon the slightest touch. Waste products are not being properly eliminated, oxidation is imperfect and blood serum, which contains the lime salts for serumal deposits, oozes in the subgingival spaces and forms an ideal medium for bacteria. These are the average gums of adults, who eat food which requires but little mastication and produces but little friction on the gums, and who take scant care of their mouths. But how quickly all of these conditions will change under artificial stimulation. The instant the gums are brushed properly, the blood starts to flow more rapidly and a new life and color make their appearance. After a thorough prophylactic treatment and a lesson in gum brushing it is not unusual to see the tissues lighten in color, possibly two or three shades in twenty-four hours. At the end of a week or ten days they assume a still lighter shade and after periods ranging from three to six months they become a light coral pink, and hold this color as long as they are daily brushed and stimulated.

There is apparently a peculiar pink shade that practically every individual may acquire if the brushing is faithfully followed. In fact this color may be taken for so sure an index, that it is easy to tell at a glance whether the patient has been brushing the teeth and gums four times daily or not. Virtue, in this case, has its own reward, for the color is always obtained when the brush has been used according to rule. The gums should be of uniform color in all parts of the mouth, the gingivæ showing no difference in shade from that of the body of the gum.

Tissue Stimulation.—If the following rules are honestly observed the same results are assured in every mouth:

1. The form of brushing as described in this chapter.
2. Brushing long enough—not less than two minutes.
3. Brushing four times a day.

Many cases have been baffling because they would not respond to treatment, but when the patient gives a demonstration at the wash bowl, it will show that he makes some omissions or uses an incorrect form of brushing which, when corrected, will bring results in a short time. Sometimes patients will claim to have followed the rules when, upon close investigation, it will be found that they have not done so.

When the gum tissue will not assume this light pink shade in six months' time, and when the patient is expert with the tooth-brush and claims to follow the rules faithfully, it may be suspected that in some way the rules are not lived up to or that otherwise a very rare exception has been found.

Evidently this color that the gums assume under the daily brushing is due to the fast flow of blood through the capillaries, the perfect oxidation of the cells and thorough removal of their waste products, as well as a thickening or toughening of the epithelial layer of cells on the surface. The festoons become pink and tough, the surface of the mucous membrane loses its thin, glassy appearance, and when dried looks tough and firm. Also when the edges of the gum are dried they do not weep. Little or no serum oozes now from this tissue and it will be noted that the serumal deposits, found so plentifully under the congested borders of the gums, almost entirely disappear at subsequent treatments. It must not be assumed that the miraculous happens under these unusual health conditions or that merely learning how to brush the gums will eliminate all present and future disease of the mouth. This is not so, but one cannot help being enthusiastic when one sees so many returns to health of the dentinal tissues under stimulation. The peridental membrane seems to acquire new life, and apparently feels the stimulation in every fiber and cell. Loose and sore teeth become tight and free from soreness, providing that too much of their supporting tissue has not been lost. Chronic cases of pericementitis disappear and even the pulp itself may be relieved of congestion if it is slight and has not progressed too far. There is no doubt but that the osteoblasts, under prophylaxis and this stimulation, do at times replace small areas of lost alveolar process. Where roots have been exposed on the labial or approximal surfaces, especially those of the incisors and cuspids, it is not uncommon to see gum tissue creep back over the exposed root to a considerable degree and on approximal surfaces there has been a filling in of the bony tissue to support the gum which is undoubtedly a new deposit of process. When it is considered that the osteoblasts are present in the peridental membrane throughout life and slowly add to the alveolar wall of the socket, it is not unreasonable to expect them to lend their aid when stimulated and the irritating cause removed.

Fig. 174 illustrates what gum brushing will do. All the teeth in this mouth were affected by pyorrhea. They were loose and the left central found to be beyond saving. The gums are a light coral pink, the teeth firm and for nearly thirteen years there has been no perceptible change in absorption or recession.

Fig. 175 shows the result of a case of acute gingivitis. This occurred eight years ago, and the exposed surface of the root at the time was nearly a third longer. By prophylaxis and gum stimulation a portion of the root was covered by new gum tissue. There has been no change in the intervening eight years.

Fig. 176 shows the right cuspid in the mouth of the same patient. This gum was also affected by acute gingivitis and the root was exposed

Fig. 174

Fig. 175

Fig. 176

nearly an eighth of an inch before the inflammation dissappeared. There was undoubtedly a replacement of lost tissue here and it has proved to be very stable.

Fig. 177 shows another case of the destructive process of acute gingivitis. Eleven years ago the indications were that this tooth could

Fig. 177

not be saved. The apex was nearly exposed and a larger area of the root uncovered. The gum tissue is now hard and pink and the tooth firm and useful.

Fig. 178 is a similar case but a year old. The conditions are bad, as the space between the lateral and central will not permit of thorough cleansing without much effort. There has been a replacement of considerable tissue, the teeth have tightened and can no doubt be retained for some time to come.

Fig. 178

It seems probable that it is not only possible to sterilize tissue by this active hyperemia, artificially induced, but also that small serumal deposits may be dissolved and disposed of by the blood or possibly by the action of the cells in these tissues. This statement does not mean that when the dental surgeon treats a case of pyorrhea alveolaris, that merely teaching the patient how to brush his gums will cause the dissolution of the deposits and kill the infection. It means that it is exceedingly important that gum brushing should be taught and the patient trained by repeated lessons until he acquires this art, for it really is an art. With the additional aid of the gum brushing the pus will soon cease, the pockets will contract and close, soreness will be relieved and any small granular deposits that may be left will gradually disappear as the tissue hugs up tightly to the root. The tissues, thus artificially stimulated, seem to possess five properties, analgesic, bactericidal, absorbent, solvent and nutritive. The analgesic effect is no doubt produced by the relief of tension and toxic influence. Whether the bactericidal effect is one of phagocytosis or of opsonins is immaterial. There is no question but that when cleanliness is established and the tissues regularly stimulated by brushing, the infection is destroyed. The absorption in the tissues is accomplished, not only by the lymphatics but by the capillaries themselves. It is a well-known fact that a ligature of catgut in the body is dissolved and disappears. Landois has shown that the blood serum of every animal has the power of dissolving the blood corpuscles from a different species. Where or how this solvent originates that causes the disappearance of the small granules of serumal deposits can only be conjectured. Induced active hyperemia will demonstrate that they do disappear. The nutritive property is self-evident, and is due chiefly to a perfect oxidizing process. There is still much to learn concerning these artificial stimulants. If the existence of human beings were more like that of animals, this condition would be induced each time that the meal of coarse food was chewed. Since the artificial rather than the animal life is preferred, and coarse food is not attractive, why should not this condition of health be produced artificially?

Tooth-brushes.—Opinions vary greatly concerning the size and shape of the tooth-brush. One educator of the middle West states in a letter that he did not recommend a hair-brush, a nail-brush or a shoe-brush for brushing the teeth, but a *tooth*-brush. His position might have received serious consideration if it were only the crowns of the teeth that were involved, but as the brushing of the gums is of equal importance with brushing the teeth, a brush that will adapt istelf to both surfaces is the one to use.

Again, if cross brushing is indulged in or a slow twisting massage or wiping motion is employed, the form and size of the brush may be varied. Personally, the writer has not been able to secure as satisfactory results with either of these forms of brushing. The cross brushing seems to irritate the festoons, at times will create absorption, and lacks the cleansing action upon the outside surfaces. The wiping motion with the sides and ends of the bristles is more cleansing and the gums take more kindly to this form of brushing, but when it is considered that nature intended that the pressure should be chiefly upward on the upper gums and downward on the lower gums, such as is induced by food sliding over the surfaces of the teeth in mastication, it can be seen that this process can be better simulated by a rotary stroke than by any other way. The gums appear to thrive under the rotary stroke, a stimulus is imparted to the circulation and a thorough cleansing effect is produced along the curved lines of the festoons and upon a third of the approximal surfaces. A slow, deliberate stroke is not as stimulating as a fast, light stroke. The best way to bring blood to the surface of a tissue in a short space of time is to use a light, rapid massage.

The results will justify the means, so a rotary stroke for the buccal and labial surfaces is advised. In order to secure the proper adaptation of a brush to the surfaces of the gums and the teeth, the shape of the bristle ends of the brush is important. Many of the popular brushes on the market are nearly concave in shape, having a long toe and heel with the shorter bristles near the center. Such a brush, placed squarely across the front teeth, seems to fit when at rest, but if slowly moved about the mouth, it will be found to ride in many places on the toe

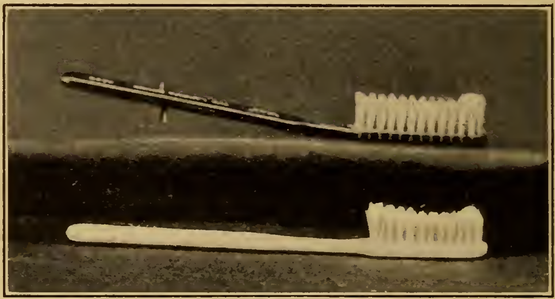

Fig. 179

and heel alone or, if pressure is used, these long bristles ride sidewise or any other way. Although the cranium is convex in shape, it has never been deemed expedient to use a concave hair-brush. In fact, a concave brush would not be as effective as a straight one, although it might seem to fit better when at rest. Apparently a straight-cut tooth-brush with a slight tuft on the end is best adapted to most of the surfaces in most mouths. The bristles should be of sufficient length to be flexible yet springy and stiff enough not to lose their life or spring after the first two or three days' use. This necessitates using a brush with bristles a trifle hard, for such a brush becomes softened after a few days' use. Fig. 179 illustrates the two shapes of brushes just referred to. When instructing a new patient in the art of brushing, a soft brush should be recommended to start with, otherwise the patient should be warned not to be too strenuous with the stiff brush until the gums have had a chance to become tough and the mucous membrane thickened, otherwise slight abrasions of the mucous membrane will be produced, and a sore and tender surface will result if the gums are brushed at first with too much pressure and vigor and with a stiff brush.

Instructions for Brushing.—The process of the brushing of the gums and the teeth may be divided into three parts:

First, the outside or buccal and labial surfaces.

Second, the inside or palatal and lingual surfaces.

Third, the occlusal or masticating surfaces of the teeth.

The Buccal and Labial Surfaces.—With the brush held in the hand, as in Fig. 180, and with the teeth nearly closed, the brush is placed inside the cheek on the left side, so that the ends of the bristles are lightly in contact with the gums over the upper molars. Now, with a fast, circular motion the brush is swept backward and downward, reaching

Fig. 180

as far down on the lower gums as the brush can travel in this position, then forward and upward as high on the gums of the upper teeth as possible (Fig. 181).

The brush should travel in a perfect circle, not in an oblong tract, and in as large a circle as the vestibule of the cheek will permit. Very little pressure should be used, for the stimulating as well as the cleansing process is accomplished by the rapidity of the stroke and the direction traveled by the ends of the bristles. Continuing this fast, circular motion the brush should be made to travel very slowly forward until the heel of the brush engages the right cuspids. Pausing on the incisors to stimulate thoroughly the gums on both jaws, start back again slowly to the region of the molars (Fig. 182).

It will be understood that the brush is constantly in motion, traveling in a large circle with the ends of the bristles lightly touching the gums and teeth with as rapid a motion as possible.

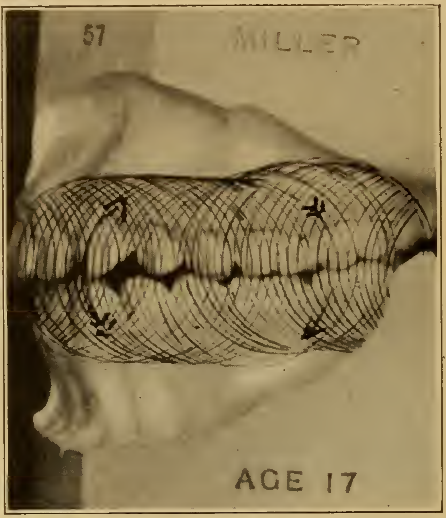

Fig. 181

Fig. 183 illustrates the position of holding the brush for the right side. On this side some persons find it easier to maintain a circular

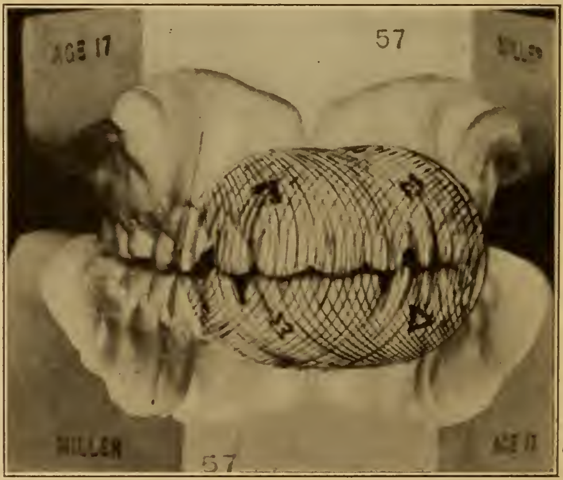

Fig. 182

motion by reversing the stroke, or brushing from the lower gums backward and upward. It makes no difference in which direction the brush travels as long as the circular stroke is adhered to. Assuming that one is using the right hand for brushing, it will not be possible to brush

FIG. 183

farther forward than the right cuspid teeth (Fig. 184). Directions for brushing the left side are applicable to the right.

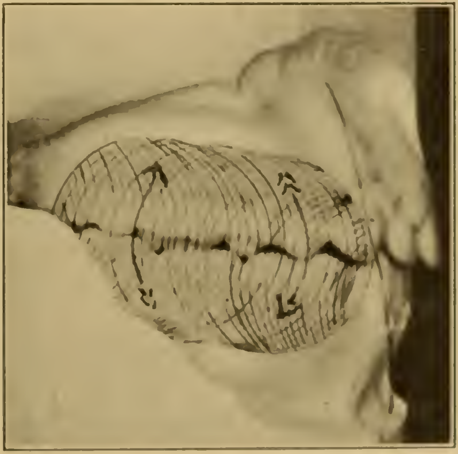

FIG. 184

Lingual Surfaces.—1. *Upper.* The brush should be held as shown in Fig. 185. The roof of the mouth as well as the lingual surfaces of the upper teeth are brushed with an in-and-out stroke, as in Fig. 186. The ends of the bristles should be placed against the gums of the right

Fig. 185

molar teeth, and the brush drawn straight forward until the heel of the brush (the last bristles nearest the hand are called the heel) wipes the lingual surfaces of the right incisors and cuspids and protrudes from the mouth for a short distance. The upper lip should be drawn

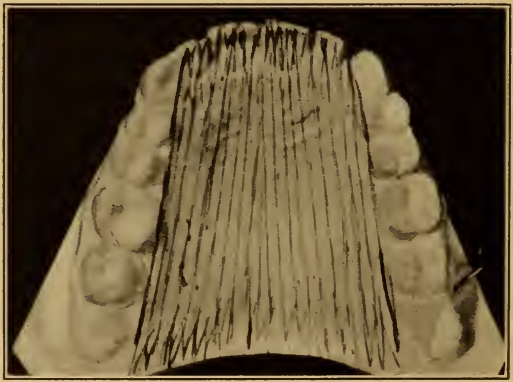

Fig 186

downward to prevent the moisture from being thrown outward by the snap of the bristles passing over the edges of the incisors. The brush is now pushed straight back again on the gums and this in-and-out stroke is rapidly made and confined on this surface for a few seconds. This fast in-and-out stroke of the brush is kept up and carried across the roof of the mouth until all of the hard palate is covered and the gums on the left side of the mouth are reached. Here the in-and-out stroke is applied rapidly for a few seconds, as far back as the distal surfaces of the third molars. The same stroke should be used on the return, the palate should be crossed to the right side again, and again back to the left side. Special care should be used to reach the gums around the last molars, there is a tendency not to brush back far enough.

2. *Lower Lingual Surfaces.*—The lingual surfaces of the lower teeth are the most difficult to brush and it takes quite a little practise before

Fig. 187

the gums can be deftly reached, especially on the right side. Nineteen out of twenty mouths will disclose a congested gingival border on the lingual surfaces of the right molars, and in order that the wrist may bend freely so that the toe of the brush may reach this surface, it is suggested that the brush be held in the hand as in Fig. 187.

These gum surfaces are brushed almost entirely with the toe or tuft of the brush, the motion being a fast in-and-out stroke, similar to that used on the hard palate, as in Fig. 188. Starting on the right side with the bristles of the tuft resting on the gum next to the last molar, the brush is drawn forward. In this case the bristles at the heel do not sweep the lower incisors as the handle of the brush is tipped slightly upward, so that the brushing is done almost entirely with the tuft.

The brush is now forced backward in the same line, leaning slightly toward the tongue, and the in-and-out stroke is applied rapidly to this surface. Maintaining always this fast stroke, and slowly coming forward, the handle of the brush is now raised to a sharp angle and the gums below the incisors are brushed with an up-and-down stroke,

Fig. 188

going back and forth across them several times. Continuing the in-and-out stroke the tuft is adapted to the gums of the left side and they are brushed in a manner similar to that described for the right side, again slowly returning to the right and repeating once more to the left side. A slight gagging sensation will sometimes be felt in trying to

Fig. 189

reach as far back as the brush should actually go, but with persistent practise this can be greatly overcome in a short time.

Masticating Surfaces.—Lastly the masticating surfaces should be brushed in order to remove any food débris in the fissures or sulci of the molars and bicuspids. The tuft of the brush should also be carried to the distal surfaces of the last molars on both the upper and lower jaws and with a wiping or twisting motion these surfaces should be cleansed.

The foregoing description of brushing gives but a stereotyped form. The mouth should be gone over three or four times until the gums begin to tingle and a slight sense of numbness is felt.

The festoons on the palatal and lingual surfaces cannot be properly brushed with the circular stroke. It may be noted that they assume a much straighter line than on the buccal surface and that the bristles traveling in and out with this straight line reach all surfaces and are more stimulating and non-irritating in their action.

In the roof of the mouth are the posterior and anterior palatine arteries which help to supply the gum tissue, hence the importance of brushing the hard palate (Fig. 189).

It should be noted that the brush is used with a full-arm motion and that a fast but light stroke is essential to secure the desired results.

Number of Daily Brushings.—Not so very many years ago more than one bathtub in a private house was considered a luxury. Today it is realized that frequent bathing is a necessity.

Some dentists advise their patients to brush their teeth before retiring; some, night and morning; and the patient who followed this last rule, thought himself virtuous indeed. The matter of brushing the teeth is purely educational and resolves itself into a habit. Time can always be found for any habit—it is merely a question of what habits are acquired.

After each meal a certain amount of food is retained on the surfaces of the teeth. In less than an hour's time this food begins to decompose. If the teeth are brushed at night and in the morning before breakfast, remnants of the breakfast remain on the teeth until bedtime, joined through the day by those of lunch and dinner. There may be some arguments in favor of not disturbing the decomposing food in the mouth all day, but such arguments are usually based on the statement that people do live with unbrushed teeth, so why handicap them with an extra daily duty when they have so little time to spare. Those who advance these arguments usually have a breath far from pleasing. It cannot be shown scientifically that a mouth containing decomposing food is as healthy and wholesome as one that is free from it.

The teeth should be thoroughly cleaned after each meal with brush and dentifrice, and given a vigorous brushing with clear water the first thing in the morning. This means four brushings a day. Of course it is not always possible to follow this rule to the letter, but where one has access to a bowl and one's tooth-brush, the teeth should be cleaned. All children should be taught this habit, as there can be no greater insurance for health and freedom from infectious diseases than a mouth free from decomposing food.

Dentifrices.—The most important ingredient in a dentifrice is soap. Next, a slight abrasive, such as a fine grade of precipitated chalk. The rest of the formula is of but little value and is used chiefly to disguise the soap and impart a pleasant taste. The removal of grease is a chemical action and soap is essential for thoroughly cleaning the teeth. If fat is rubbed on the hands or on a slab of glass it will be difficult to remove it with clear water and a brush. Although with considerable effort it may be done, soap will remove it much more quickly. A fine grade of powdered Castile soap is the best, but it is seldom found in the preparations on the market, as it does not give sufficient lather to suit either manufacturer or purchaser. The most harmful element in a dentifrice is the use of cheap coarse grades of chalk. In fact some preparations contain pumice and in one foreign production, powdered oyster shells were found. The teeth should be cleaned, not scoured, and the daily use of a gritty dentifrice will eventually cause abrasion of the thin enamel surfaces at the necks of the teeth. The grit may be readily detected by placing some of the paste or powder between the teeth and biting on it. Finer tests may be made by putting it between two glass surfaces, rubbing them together and examining them with a magnifying glass.

A slight abrasive is helpful in aiding in the removal of the slippery film of mucin and viscid accretions on the surfaces of the teeth. Its daily use is harmless providing the grit is fairly soluble and not coarse. When one computes the number of occlusions that take place daily between the masticating surfaces of the teeth during the three meals and notes what little wear of the enamel cusps is exhibited at thirty-five or forty years of age, it may be concluded that the use of a fine grade of precipitated chalk as a base for a dentifrice is not a serious menace to the enamel tissues. There is but little choice between powder and paste, as regards efficiency. Powder has to be worked into a paste-like condition in the mouth with the brush, while paste quickly spreads itself over the teeth for immediate action. The majority of people find the paste much pleasanter to use. The difference in the formulæ of the two preparations consists in leaving out the saccharin in the powder and mixing the powders and oils with glycerin to form paste.

A simple, cheap and effective powder may be made by placing the following ingredients, all of which may be bought at any drug-store, in a quart Mason jar:

Finest grade English precipitated chalk	$\frac{1}{2}$ pound
Powdered Castile soap	$1\frac{3}{4}$ ounces
Light carbonate of magnesia	$\frac{1}{3}$ ounce
Oil of clove	46 drops
Oil of wintergreen	35 "
Oil of sassafras	35 "
Oil of peppermint	18 "
Saccharin—finely powdered	4 grains

The glass top should be securely fastened on and the contents shaken vigorously. This mixing process takes some time, but as it takes at least twenty-four hours for the oils to permeate the powders, the jar may be picked up at varying intervals and its contents thoroughly shaken. A larger bottle with the same quantity of powder will permit of a more thorough mixing in a shorter time.

The brush should be very wet when the powder is placed upon it and care should be taken not to inhale when introducing the brush into the mouth.

A properly prepared tooth paste is a much pleasanter toilet article to use and, as there are some on the market quite effective and harmless, one of these may be recommended to patients for use.

Each tooth has five surfaces. Three of these can be cleaned with the brush, but the two approximal surfaces, the most susceptible of all, cannot be reached with it. In other words three-fifths of the surfaces of the teeth can be cleaned with the tooth-brush but not the remaining two-fifths which most need it. It should then be apparent that if all the food is to be cleaned off all the surfaces of all the teeth, additional means of so doing must be employed other than the tooth-brush. Up to the present time nothing is known that will accomplish this more efficiently and harmlessly than the floss silk and lime-water.

Fig. 190

Floss Silk.—If the floss silk is skilfully and frequently used, the approximal surfaces may be kept quite free from dental caries. To induce patients to use the floss silk with regularity is a task, but by being persistent in requesting and logical in the reason for its use, they may be made gradually to acquire the floss habit. To insure the proper use of the floss the fillings in the approximal surfaces should be smooth and polished, with just sufficient pressure at the contact points to allow the floss to snap through without too much effort in forcing it. Care

Fig. 191

should also be taken not to allow the floss to snap through on the gum tissue hard enough to wound it. There is but little danger of this

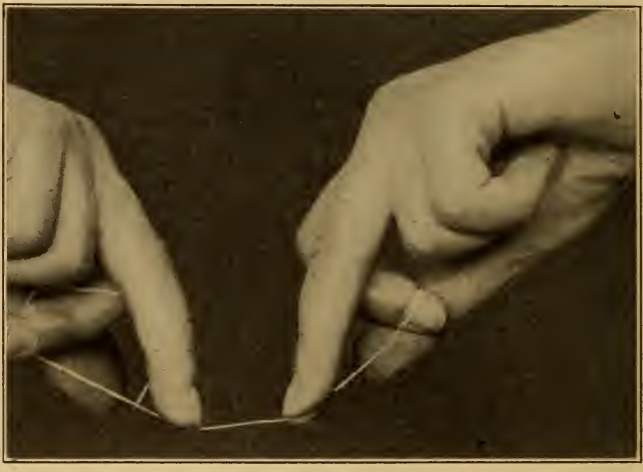

Fig. 192

after a little practise, especially after the gums have become hard and tough from brushing. A reasonably small-sized waxed floss is the best to use. For adults the piece should be fourteen or fifteen inches in length. The end of the floss is taken between the thumb and first finger of the left hand and two wraps made around the end of the first finger, and this act repeated with the other end of the floss on the

FIG. 193

FIG. 194

right forefinger. The floss is now held securely and will permit the ends of the two thumbs or the two second fingers or a combination of a thumb of one hand and a second finger of the other, to guide the silk into its position in the mouth and force it between the teeth. Fig. 190 shows adaptation of floss for right upper teeth. Fig. 191 shows adaptation for left upper teeth. Fig. 192 shows adaptation for all the lower teeth. After the floss has passed through the contact points it should be rubbed back and forth against both approximal surfaces to polish them mechanically. In withdrawing the floss, if the end held opposite the lingual surface is brought over on the buccal surface and the silk is pulled through the contact points in the form of a loop, it will be more effective in polishing or cleaning these surfaces than if merely snapped out (Figs. 193 and 194). The floss will not, however, thoroughly remove all the food between the teeth, therefore we must have recourse to a mouth wash.

Lime-water.—Practically all the mouth washes on the market are formulated to accomplish two results. First, a neutralizing action, either acid or alkaline, and second, a germicidal action. It will readily be understood that the latter result cannot be obtained in the mouth, while the former is immaterial. In order to secure immunity to decay, the bacteria must be robbed of any pabulum upon which to feed and any placques or glue-like accumulations on the surfaces of the teeth must be dissolved.

Acid mouth washes have been advocated because it has been found that the lactic acid forming bacteria are retarded in their growth and activity in an acid medium. Alkaline washes have been prescribed because of the belief that they will neutralize any lactic acid formed that will induce caries. Both of these theories are based on partial facts only, for it has been absolutely proved that the chemical action of an acid or an alkali used as a mouth wash for neutralizing purposes will not inhibit dental caries to any great degree. All of these washes are supposed to contain germicides that will immediately destroy the microörganisms of the mouth. This is of course untrue, especially when the short time they are retained in the mouth for this purpose is considered. The peroxide of hydrogen is religiously used by many, in the belief that the oxygen liberated is a germicide of sufficient power to destroy all the bacteria. The mechanical action of the peroxide in its boiling process, while it does liberate the oxygen, is more effective in dislodging particles of food débris around the necks of the teeth than in its germicidal action on the organisms in the mouth. In the study of dental caries it must be concluded from the present knowledge of the subject that in the main Professor Miller's theory still holds good, namely, that the exciting cause is due to the production of lactic acid by the action of microörganisms on carbohydrates, and that decay takes place most readily on those surfaces least exposed to friction during mastication, such as the fissures or pits, approximal surfaces, and the necks of the teeth. Dr. J. Leon

Williams was the first to point out the fact that a thin gelatinous placque was first formed on the surface of the enamel and under and in this thin film the bacteria obtained a secure position that made their dislodgement difficult. Their action in the production of acid was intensified when thus protected. Other scientific investigators have corroborated Williams' observations. The mucin, which is a product of the salivary and mucous glands, plays an important part in the formation of these placques. Laying aside any theories regarding susceptibility and immunity, it must be admitted that the battle just now should be the thorough removal of all food débris and the removal of these placques and glue-like accretions.

At the present time there is considerable agitation in dental circles regarding the use of fruit acids to prevent dental caries. Mucin is precipitated from the secretions in the mouth by the presence of an acid. This precipitate forms on the surfaces of the teeth and becomes the factor in incasing the bacteria with food débris and in forming the so-called placques. Mucin thus precipitated is soluble in or may be dissolved by an alkali. It has been found that the presence of fruit acids in the mouth excites a flow of saliva which possesses quite a strong alkaline reaction. It is claimed by these investigators that the increased alkalinity of the saliva has a solvent action on the precipitated mucin and a neutralizing action on lactic acid and thus becomes a natural preventive of dental caries. Other investigators have as yet been unable to find that the alkalinity so produced is of sufficient strength to have this solvent action. Again, it is claimed that the acids of fruits have a curdling effect on the mucin, forming it into flakes which are easily removed from the tooth surfaces.

There is a serious question concerning the habitual use of these acids for this purpose. Practically all of the acids of fruits, especially those of oranges and lemons, if used too freely will in time act as solvents for the cementing substances between the enamel rods. If the deductions of these investigators were entirely correct the inhabitants of the tropics would be found to be quite free from dental caries, which of course is not the case. Williams has observed that the peasants working in the orange and lemon groves of Sicily were quite immune to caries, and Pickerill also cites the natives of New Zealand as an example. The Italians and the Sicilians are very fond of hard bread and coarse food, and if a scientific investigation were made regarding their immunity to caries other powerful factors would be found besides the fruit acids. Those who live in the orange groves of Florida are far from being immune, in fact the reverse is the rule. The American Indian, who did not eat much fruit, enjoyed a considerable immunity from caries. In fact, if every one lived an out-of-door life, eating coarse food and less sugar, there would be but little need of the dentist. A reasonable amount of fruit is healthful and desirable, but dentifrices and mouth washes containing fruit acids, must be used with considerable judgment.

If it can be scientifically shown that dentifrices and mouth washes containing fruit acids in certain proportions are harmless to the teeth and the tissues of the mouth and are superior to any of the present-day preparations as prophylactic agents for dental caries, it would prove to be a valuable contribution to dental prophylaxis.

As it will take a number of years to demonstrate this as a fact it will be necessary for the present to adhere to those agents that have proven themselves to be harmless and efficient in the past.

The most cleansing and the least harmful of all fruits is the apple. This with its dense texture acts as a mechanical cleanser, and the malic acid is comparatively harmless. Where it is impossible to have access to a tooth-brush the eating of an apple will be found an excellent substitute.

There is a solvent for the placques and accretions on the surfaces of the teeth that is quite positive in its action. This solvent is lime-water, and is made from the coarse calcium oxid or unslaked lime. Its preparation is simple and cheap, and when its efficiency for the use and purpose intended is considered, it will rank as an important agent for the prevention of dental caries.

Some coarse lime, such as is used in making rough plaster, may be secured from a paint store or from a mason. The refined product found in the drug-stores apparently does not have the same effect. The refining process robs it of some of its beneficial properties. It is cream white in color. The lumps should be broken up into coarse powder and a half-cupful put into a quart bottle. The bottle should be nearly filled with cold water, room enough being left to permit of thorough shaking, shaken vigorously and set aside for three or four hours to allow the lime to settle. Then as much of the clear water as possible should be poured off, for this contains the washings of the lime. It will be found impossible to pour off all the water without losing some of the lime, but by pouring slowly nearly two-thirds may be drawn off. The bottle can then be filled with cold water and shaken thoroughly, when, after it has settled again, it will be ready for use. A bottle of convenient size should be procured; one holding ten or twelve ounces, and filled with the clear water from the large bottle. This smaller bottle will be more convenient to use at the bowl. The large bottle can be again filled with cold water, shaken thoroughly and set aside to be used as needed (Fig. 195). This operation may be repeated over and over again, for the original half-cupful of lime will make five or six quarts of lime-water. If the first use of the wash proves that it is a little strong, it can be diluted in the small bottle. With new patients and those having tender gums it may have to be diluted, but as soon as possible it should be used undiluted. When taken into the mouth it should be forced back and forth vigorously between the teeth with the tongue and cheeks and the rinsing continued until it breaks into a foam. Not that there is any particularly beneficent action to the foaming, but if it is worked through the teeth long enough to make the foam it will have been in contact with the surfaces of the teeth long enough to have a solvent action on the placques and accretions. Afterward the mouth should be thoroughly rinsed with warm water to take away the taste of the lime-water. It is the unpleasant taste of the lime that makes it difficult to induce the patients to use it at the start, but after a short time the cleansing effect is so pleasing that they soon forget about the taste. It may be flavored with saccharin or any flavoring material, but this will hardly be found necessary. The lime-water should be used after the brushing and flossing, after each meal.

Fig. 195

Summary of Prophylaxis.—One prophylactic treatment does not constitute prophylaxis. It is only by a systematic, continuous course of treatment and home care of the mouth that these ideal conditions can be secured. It is estimated that all great educational movements that possess real merit take thirty years for their final acceptance and adoption. Mouth hygiene has been agitated for fifteen years. The next fifteen years will see its rapid spread throughout the country and its practise quite general.

Preventive dentistry can be had quite cheaply and is within the reach, financially, of nearly everybody. Good operative dentistry is expensive and always will be, as is surgery or the services of any educated and skilled specialist.

Prophylaxis is the only hope of solving the dental problems for the masses and as time goes on it will be found as necessary a form of insurance for health as life insurance is for the protection of those left after one dies.

When the public really becomes educated to the fact that for the expenditure of a very moderate sum of money and a little energy on their part, they may retain their teeth throughout life quite free from pain and disease, there will be a great demand for this form of service. Every mouth would be greatly benefited if these treatments could be administered every two months. Many mouths require monthly treatments, especially those of children and adults who are susceptible to caries.

In an analysis of susceptibility it will be found, in many cases, that the individual is indulging in too much candy and free sugars. Children are given crackers or cookies just before going to bed, and not infrequently in bed, to keep them quiet. Women and children especially are fond of sweets, and it is the promiscuous eating of them between meals that creates such havoc with the teeth.

England, France and America are consuming too much sugar. An educational campaign to check this large consumption would be of great help in our problem. Statistics show that the countries where the greatest amount of sugar is eaten are the countries where the worst conditions of teeth are found. The sugar consumption per capita has increased amazingly during the past forty years and so has dental caries. If dentistry, as a science, had not advanced so rapidly during this same period, ruined mouths would be even more prevalent.

In the search for some easy solution of the problem of dental decay many ideas are advanced for its ultimate control, and it is expected that a simple method of doing away with this great disease-producing disorder will be found. There may come a time when a lozenge will produce immunity but that time is not in sight as yet. As long as people live artificially, as most people do, eating the various concoctions called "food" that they feel free to eat at the present time, the one hope of escape from the ill-effects of dental decay and its attending serious effects on the body is through the present knowledge of extreme cleanliness, or mouth hygiene. Until something can be presented more definitely simple that will show equally beneficial results, it will be necessary to adhere to the form of prophylaxis herein advocated.

SOME OFFICE FACTS AND STATISTICS.

In the writer's practice many cases of interest have been observed; individual cases, however, always lack force, for there may be a question of doubt about them, but a demonstration made by thirty or forty people simultaneously permits of comparisons and brings conviction to even doubting minds.

This enthusiasm in oral prophylaxis is due to the ideal health conditions obtained in the mouths of patients, to their consequent physical betterment and to their hearty endorsement.

In the early part of the year 1914 the following letter was sent to two hundred of the writer's patients:

BRIDGEPORT, CONN., January, 1914.

MY DEAR ———,

In preparing some lectures on the subject of prophylaxis, I have found it desirable to offer some facts and statistics concerning my own practice, and would consider it a personal favor if you would kindly fill out the enclosed card and return it to me.

It is not my intention to use any names or any individual cards. I merely wish to get at the truth to verify statements I have felt warranted in making concerning the comparative immunity from sickness when the mouth is kept in a clean and wholesome manner.

We know that many of the infectious diseases of childhood emanate from unsanitary mouths, these with their decayed teeth and decomposing food débris being ideal incubators for germ life. We know, too, that in adults whose mouths are unclean and diseased, the intestinal tract as well as the whole nutritive system is seriously disturbed and organic infections are frequently produced. A clean, sanitary mouth is not, of course, a panacea for all of our ailments, but we know that it is a powerful factor for good health.

It is a fact, frequently mentioned at my office, that it is extremely rare for a patient to cancel an appointment on account of illness, and I feel it would be helpful to the dental profession in advancing this work of prevention if additional facts of this nature could be secured.

I realize that it is something of an imposition and rather an unprecedented thing to do, but feel that the cause involved is sufficiently great to warrant my asking this favor.

If for any reason you would rather not fill out the card please feel free to ignore it.

Yours very sincerely,
ALFRED C. FONES.

With this letter was enclosed a card on which were printed the following questions:

Name . . . .
Have you been ill during 1913? . . . .
If so, was the illness of long duration? . . . .
If you do not object will you state illness? . . . .
Do you feel that mouth hygiene has benefited you physically? . . .
Any remarks . . . .
Signed . . . .

The object in sending these letters and cards was to secure some data relative to the physical influence of mouth hygiene upon the everyday life of both children and adults and also to get an expression of opinion as to whether or not mouth hygiene, as a factor for good health, was appreciated by the patients. Perhaps the last question was not very fortunately worded. It was not expected that the patients would experience any pronounced glow of health coming over them after following the system of mouth cleanliness for a period of time; still in spite of this perplexing question the answers were both interesting and quite satisfactory, as the tables will show. At the time it became necessary to use this data, one hundred and sixty cards had been returned, or 80 per cent. of those sent out.

A study of the following tables of the answers returned will at least prove interesting, even if no scientific data are found.

To the question, "Have you been ill during 1913?" the cards showed the following answers:

14 stated illness.
11 had colds (now and then).
135 had no illness.

These figures show that 85 per cent. of these patients had been free from all sickness.

Of the fourteen who had been ill the following table gives details:

Illness.	Number.	Duration of illness.	Child.	Adult.
Grippe	2	3 days each	1	1
Tonsillitis	2	4 days—2 weeks	..	2
Nervous trouble	1	"Not long"	..	1
Whooping-cough	1	"Quite long"	..	1
Acute indigestion	1	2 days	..	1
Appendicitis	2	4 weeks—"not long"	..	2
Pleurisy	2	1 week—"not long"	1	1
Sore throat	2	5 days—"not long"	..	2
Bronchitis	1	"A few days"	..	1

Although a diseased or unsanitary mouth would be capable of producing most of the ailments noted in this list, it must be remembered that these patients present healthy mouths and are reasonably faithful in their care.

Under such conditions it would seem justifiable to eliminate the following from the table:

Two cases of appendicitis, the operation for one of which had been previously planned for two months and the other one being a recurrent attack soon controlled and not requiring an operation, one of acute indigestion, one nervous trouble, and two of pleurisy.

This list, under the above conditions, would not be susceptible to serious debate as being caused through mouth infection. The remaining ailments partially prove that mouth hygiene does not secure absolute immunity to infectious diseases, yet it must be conceded that the length of illness, with the exception of the two weeks of tonsillitis, is surprisingly short. If the eleven who stated "colds now and then" are eliminated and charged up to overfeeding, there are, as a last analysis, eight people out of one hundred and sixty who were ill during 1913 with forms of illness from which to the writer's mind, mouth hygiene should have made them immune. To try to claim everything in sight would be discourteous to the medical profession, but in a broad sense it may be stated that, omitting the list of colds, over 90 per cent. were free from sickness and ninety-five were free from infectious diseases.

Considerable interest may be found in the answers to the last question which was:

"Do you feel that mouth hygiene has benefited you physically?"

53 answered "Yes."
10 answered "Cannot say."
3 space blank, no comment.
37 stated an appreciation of prophylaxis.
51 specific statements of physical betterment.

This question was inspired by the comment of numerous dentists who had stated that patients would have but little appreciation of prophylaxis. If the question had been instead, "Do you feel that mouth hygiene is a physical benefit?" it would have shown whether or not the patients had an understanding of its importance and would in itself have answered the comments.

Considering the blunt way the question appeared on the card, the answers were highly satisfactory, and although they give no scientific data, they surely indicate a reasonable degree of enthusiasm for the science of prophylaxis. Twenty-seven stated their appreciation without comments of physical betterment. Fifty-one stated, in a general way, that they felt mouth hygiene had benefited their general health and six named the disappearance of their ailments. Of the latter two had recovered from chronic indigestion, one noted the disappearance of headaches, and three stated the disappearance of throat irritation.

It must be remembered that these cards form a record of but one hundred and sixty people of all ages for but one year. Whether an additional one hundred and sixty cards would add to the interest of these tables is hard to determine without trying it out. Scientific facts cannot be based on any general investigation of this kind, but it must be admitted that the evidence submitted is at least favorable to mouth hygiene.

A SYSTEM FOR PROPHYLAXIS IN DENTAL PRACTICE.

First a new patient is given two appointments, a week or ten days apart, with the dental hygienist, for a thorough instrumentation and polishing of the teeth.

At the end of the first sitting he is supplied with a tooth-brush, dentifrice, floss silk and lime-water for a mouth wash, taken to a wash bowl and taught how to properly brush teeth and gums, and given full instructions in the home care of the mouth.

At the end of the second sitting one-half hour is reserved for him with the dentist for a thorough chart examination. Appointments are then arranged and the teeth restored to a sound condition. At the end of the last appointment the dentist gives the patient a thorough prophylactic treatment.

The patient is then put on a list and sent for each month for a treatment by the dental hygienist. At the end of six months he again goes into the hands of the dentist for a thorough prophylactic treatment and examination of the teeth and gums and if the condition of his mouth warrants, the interval between the treatments is now lengthened to six weeks. At the end of the next six months he again goes through the dentist's hands and if good mouth health is attained his name is placed on a two months' list and he is given treatments by the dental hygienist at these intervals, going into the dentist's hands for every third treatment, or once in six months. Patients whose mouths are very susceptible to dental caries, such as children and young people, should be retained on the monthly or six weeks' list.

When the patient's mouth has been put in order and his name placed on one of the lists to be sent for at regular intervals, his name is also entered in the appointment book against the date when his next appointment for a prophylactic treatment falls due. A week previous to this date the patient is notified of the appointment by means of a return card system. This consists of an appointment card bearing the name of the patient and date and hour of his appointment, a return card bearing the same date, and a stamped return envelope. If the date designated proves convenient, the patient signs the return card and returns it in the enclosed envelope and the appointment is checked in the appointment book. If not convenient, a new appointment is made. The various lists of patients—monthly, six weeks and two months—are kept by means of a card-index file.

CHAPTER XIII.

CHEMISTRY OF FOOD AND NUTRITION.

By RUSSELL H. CHITTENDEN, Ph.D., LL.D. Sc.D.

Part I.

In a popular sense, under the term food is included all those substances which man, following the dictates of a capricious appetite, is in the habit of eating. In this sense, food comprises a large number of substances or products belonging to the animal and the vegetable kingdoms. If, however, we attempt a chemical analysis of the various foods which man is accustomed to eat, it is found that they contain one or more of six distinct classes or principles. These are known as proteins, albuminoids, fats, carbohydrates, inorganic salts or mineral matter, and water.

In a physiological sense, a food is a substance which helps maintain the integrity of the body tissues, thus insuring a normal condition of the body protoplasm. This implies not merely the integrity of the tissues of the body as a whole, but likewise the integrity of each individual unit of the tissues, *i. e.*, the tissue cells. Food must supply material for the growth of new tissue as in the young, and for the repair or maintenance of wasting tissues in the adult.

Further, a food, in the strict physiological sense, must not only contribute to the maintenance of the tissues, but it must likewise furnish energy to meet the daily needs of the body; energy which will manifest itself in the form of heat or work, as the case may be. It should also help maintain and strengthen the defenses of the body against disease, or disease germs. In other words, physiologically speaking, a food must help keep up the normal nutritional rhythm of the body. Again, a food, if it conforms to the physiological definition, must not be in any sense inimical, or harmful, to any of the tissues or any of the processes of the body.

Of the various food principles, the proteins taken as a class are, for many reasons, the most important. They are composed of carbon, hydrogen, nitrogen, oxygen, sulphur, and some contain phosphorus. As a rule they contain approximately 52 per cent. of carbon, 7 per cent. of hydrogen, 16 per cent. of nitrogen, 22 per cent. of oxygen, 0.5 to 2 per cent. of sulphur, the phosphorus when present being contained ordinarily in small amount. Protein foodstuffs are widely distributed throughout the animal and vegetable kingdoms, and while they differ somewhat among themselves, both in chemical composition and in physiological behavior, they are alike in containing approximately 16 per cent. of nitrogen. They are therefore referred to as nitrogenous foods. Proteins, furthermore, are likewise spoken of as essential foods, because they are absolutely essential for life. In the definition given of a food, it was stated that a food is a substance which helps maintain the integrity or normal condition of the tissues of the body, which means as well the condition of the cell protoplasm. The functional activity of a tissue, whatever it may be, depends upon the functional activity of the individual elements of that tissue, *i. e.*, the tissue cells, and the chemical basis of a cell is the cell protoplasm. Again, the important part of the cell protoplasm is the protein material which it contains. Every living cell of the body, whatever its nature, whatever its origin, whether it be an exceedingly active tissue like the muscle tissue or brain tissue, or whether it be a very inactive tissue like bone and teeth, is made up of cell protoplasm, and the cell protoplasm in every case is composed largely of protein material. These tissue cells, or their contained protoplasm, are not able to renew the waste of cell substances except through the intake of protein food. Growing tissues likewise are dependent upon the intake of fresh protein material to accomplish growth. The nitrogenous or protein foods are therefore essential foods, necessary for maintenance and for growth. In no other way than by the intake of protein food can the protein material of cell protoplasm be renewed.

As has been stated, phosphorus is not common to all proteins; but there is a certain group of very important proteins practically present in all tissue cells, and consequently playing a very important part in nutrition, substances which contain phosphorus in quite appreciable amounts. These phosphorized proteins are generally termed nucleoproteins, since they are composed of a peculiar phosphorized substance known as nuclein or nucleic acid combined with protein.

Albuminoids are substances closely related to the proteins, containing nitrogen in essentially the same amount as a true protein in addition to carbon, hydrogen, oxygen and sulphur, but they differ from the proteins proper in that they have a different nutritional value. Gelatin is a typical albuminoid, a substance which, while resembling protein in many respects, is not able to support life to the same degree that a true protein can.

As distinguished from the proteins, fats and carbohydrates are frequently termed non-nitrogenous foods, owing to the fact that they contain no nitrogen, but are composed solely of carbon, hydrogen, and oxygen. Carbohydrates contain approximately 40 per cent. of carbon, while the hydrogen and oxygen present are in such proportions as to form a certain number of molecules of water; hence the name carbohydrates. Fats, on the other hand, contain far more carbon than the carbohydrates, approximately 75 per cent. or more, and on account of this larger proportion of carbon have a higher calorific value or heat-producing power than carbohydrates possess.

The inorganic salts or mineral matter, which are present in practically all foodstuffs in greater or less degree, play an important part in the nutrition of the body, being necessary for the development and growth of such solid tissues as bone and teeth. Many inorganic salts play a part likewise in influencing certain of the nutritional processes. They are present in the protoplasm of all tissues and are essential, as is also water, in helping to maintain the normal composition of the body tissues. Of the inorganic salts especially conspicuous are phosphates, chlorides and sulphates of sodium, potassium, calcium, magnesium, and iron.

THE CHEMICAL COMPOSITION OF SOME COMMON FOOD MATERIALS.[1]

Food materials.	Protein, per cent.	Carbo-hydrate, per cent.	Fat, per cent.	Water, per cent.	Mineral matter, per cent.	Fuel value per pound, calories.
Fresh beef, round, lean, edible part	22.3	0	2.8	73.6	1.3	540
Fresh porterhouse steak, edible part	21.9	0	20.4	60.0	1.0	1270
Fresh beef liver	21.0	1.7	4.5	71.2	1.6	605
Fresh beef tongue	19.0	0	9.2	70.8	1.0	740
Fresh sweetbreads	16.8	0	12.1	70.9	1.6	825
Cooked beef, roasted	22.3	0	28.6	48.2	1.3	1620
Broiled tenderloin steak	23.5	0	20.4	54.8	1.2	1300
Lamb chops, broiled	21.7	0	29.9	47.6	1 3	1665
Chicken, broilers, edible part	21.5	0	2.5	74.8	1.1	505
Roast turkey, edible part	27.8	0	18.4	52.0	1.2	1295
Fricasseed chicken, edible part	17.6	2.4	11.5	67.5	1.0	855
Fresh mackerel, edible part	18.7	0	7.1	73.4	1.2	645
Fresh halibut, steaks	18.6	0	5.2	75.4	1.0	565
Fresh oysters, solid	6.0	3.3	1.3	88.3	1.1	230
Fresh hen's eggs	13.4	0	10.5	73.7	1.0	720
Butter	1.0	0	85.0	11.0	3.0	3605
Full cream cheese	25.9	2.4	33.7	34.2	3.8	1950
Whole cow's milk	3.3	5.0	4.0	87.0	0.7	325
Oatmeal	16.1	67.5	7.2	7.3	1.9	1860
Rice	8.0	79.0	0.3	12.3	0.4	1630
Wheat flour, entire wheat	13.8	71.9	1.9	11.4	1.0	1675
Shredded wheat	10.5	77.9	1.4	8.1	2.1	1700
Macaroni	13.4	74.1	0.9	10.3	1.3	1665
Wheat bread or rolls	8.9	56.7	4.1	29.2	1.1	1395
Soda crackers	9.8	73.1	9.1	5.9	2 1	1925
Fresh asparagus	1.8	3.3	0.2	94.0	0.7	105
Dried beans	22.5	59.6	1.8	12.6	3.5	1605
Dried peas	24.6	62.0	1.0	9.5	2.9	1655
Green peas	7.7	16.9	0.5	74.6	1.0	465
Boiled potatoes	2.5	20.9	0.1	75.5	1.0	440
Apples, edible part	0.4	14.2	0.5	84.6	3.0	290
Bananas, yellow, edible part	1.3	22.0	0.6	75.3	0.8	460
Fresh strawberries	1.0	7.4	0.6	90.4	0.6	180
Almonds, edible part	21.0	17.3	54.9	4.8	2.0	3030
Peanuts, edible part	25.8	24.4	38.6	9.2	2.0	2560
Pine nuts, edible part	33.9	6.9	49.4	6.4	3.4	2845

By chemical analysis of food materials one learns regarding the proportion of protein, carbohydrate, fat, etc., present therein. The preceding table gives a few data bearing on the composition of some

[1] Bulletin 28, U. S. Department of Agriculture, Experiment Station Bulletin.

common food materials. The last column of figures, showing fuel value per pound, will be considered later. It is to be noted, first, that all ordinary food products contain a large amount of water. Water is a very important part of food, just as it is an important part of the tissues of the body. Fresh meats, for example, contain approximately 70–75 per cent. of water; but when roasted or broiled a large proportion of this water is evaporated. Thus, while fresh lean beef may have 73 per cent. of water in it, roasted beef may contain only 48 per cent. Some animal foods, such as oysters, contain a relatively small amount of solid matter—12 per cent. only, as seen in the table. Similarly, among vegetable foods, such articles as fresh asparagus, strawberries, etc., are likewise poor in solid matter; 6–10 per cent. The more important points regarding the composition of foodstuffs to be emphasized, however, are (1) that foods of animal origin are, as a rule, rich in protein and contain little or no carbohydrate; (2) that foods of vegetable origin are ordinarily very rich in carbohydrate matter, some containing only a comparatively small amount of protein, while others, such as peas, beans, nuts, etc., may contain as much protein as ordinary animal food. In milk, after eliminating the water, all three of the organic food principles are equally conspicuous. In edible nuts also, such as almonds and peanuts, protein, carbohydrate and fat are all three present in large amounts; fat being especially abundant. In some nuts, such as pine nuts, carbohydrate may be present in a relatively small amount, thus constituting a food rich in protein and fat, but poor in carbohydrate.

The carbohydrates of our food supply are mainly in the form of starches, abundant in cereals and other vegetable foodstuffs. Sugars, gums, etc., are likewise abundant components of the daily food. All carbohydrates are made available for the needs of the body by digestion, and are eventually absorbed into the blood as simple sugars, chiefly dextrose, but in some measure also as levulose and galactose. Carbohydrates may be divided into three groups; polysaccharides, of which starch is a type; disaccharides, such as cane sugar, milk sugar, and maltose, and monosaccharides, such as dextrose, levulose, and galactose. It is only in the form of monosaccharides, or simple sugars, that carbohydrates can be utilized directly by the body. Consequently, it is the purpose of digestion through the enzymes of the digestive juices to transform the polysaccharides, such as starch, and the disaccharides, such as cane sugar, into the monosaccharides dextrose, galactose, etc. Eventually the carbohydrates taken into the body as food are oxidized in the tissues to carbon dioxid and water. The chief value of carbohydrate food to the body is that it constitutes a source of energy for the needs of the tissue cells, expecially for muscular work, and as a supply for the heat needed by the body. A gram of sugar yields on oxidation four calories of heat, and in this connection it is to be remembered that carbohydrates form the largest part of the daily diet. Further, as they are easily oxidized in the body, they constitute, therefore, especially available material for maintaining the supply of animal heat. At the same time, as already stated, the body can utilize directly only the monosaccharides. Cane sugar, for example, though soluble and diffusible, is not directly available for the needs of the body, but must be split apart by an appropriate ferment or invert enzyme into the two molecules of a monosaccharide.

$$\underset{\text{Saccharose.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Levulose.}}{C_6H_{12}O_6}$$

Similarly, milk sugar must undergo inversion into the monosaccharides dextrose and galactose, as a preliminary step in its utilization by the body. It is plain from the chemical composition of carbohydrates, lacking as they do nitrogen, that they cannot by themselves serve to build up protoplasm. Man cannot live on carbohydrate food alone, no matter how abundantly supplied. He would eventually starve to death owing to lack of protein food; but as we shall see later on, the carbohydrates serve to protect protein material in some degree. The energy which is furnished by their oxidation helps to maintain the supply of heat and enables the tissues of the body to obtain the energy needed for their special kinds of work, and in this way the carbohydrate foods protect the protein of the tissues of the body, enabling the body to maintain a good nutritive condition on a reduced amount of protein food. Lastly, it should be mentioned that carbohydrate taken as food in quantities greater than is needed for the immediate wants of the body is stored up in the form of glycogen in the liver, or it may be transformed into fat and deposited in the various tissues of the body.

The fats contained in the daily diet by their oxidation furnish a part of the heat energy needed to maintain the body temperature; their high calorific value making them more effective in this respect than carbohydrates. Likewise fats are stored in the various tissues of the body, thus constituting a reserve which can be drawn upon in case of deficiency of food or during complete fasting. Like carbohydrates, fat also protects the protein of the tissue from consumption. On the other hand, fats are not so easily digested as carbohydrates, and hence their energy value is not so readily available as that of carbohydrates.

The processes of nutrition, or the chemical changes of metabolism, are essentially exothermic, *i. e.*, they are attended by the production of heat. The term "metabolism" includes practically all those changes that occur in our foodstuffs from the time they are absorbed in the alimentary canal until they are cast out of the body in the various excretions. The digested food material absorbed from the gastro-intestinal tract by the blood is carried to the tissues, and is there, in part at least, transformed into the living protoplasm of the cell. This building up of cell protoplasm from the food material is an *anabolic* process. The breaking down of the material of the tissue cells is, on the other hand, a *catabolic* process. The breaking down of the complex molecules, either of food material or of the tissues, is primarily the result of oxidation. These processes of oxidation may be slow or they may be rapid, but in any case the ultimate products are essentially the same. The carbon of the protein molecule, the carbon of the fat, or the carbon of the carbohydrate, is eventually oxidized to carbon dioxid.

Similarly, hydrogen and sulphur of the protein molecule are oxidized to water and sulphur dioxid; the latter eventually appearing in the excretion as a salt of sulphuric acid. In the case of nucleoproteins, the phosphorus is oxidized somewhere in the body with the formation of phosphoric acid, which eventually combines with an alkali or with an alkali earth, and thus there results, for example, sodium phosphate or it may be calcium phosphate. As calcium phosphate it may be deposited in the teeth or in the bones, making a noticeable part of these solid tissues.

As has been stated, the processes of oxidation, the processes of metabolism, as they occur in the body, are usually slow. Whereas, protein, fat or carbohydrate oxidized outside of the body are broken down at once into the ultimate simple products, such as carbon dioxid, water, etc., in the body the steps are quite different. Sir Michael Foster once said that the processes of metabolism, so far as we can measure them, may be compared to a flight of stairs. The complex protein molecule, for example, taken into the body as food and eventually made a component part of the tissues, starts on its catabolic changes, breaking down step by step into simpler compounds, until at last the final end-products, carbon dioxid, water, sulphur dioxid, urea, etc., are formed. Each step in the process corresponds to a step in the flight of stairs. As a rule, then, we see that the metabolic processes are gradual, step by step. Sugar, for example, or carbohydrate food in general, is probably broken down and oxidized by the successive action of a series of enzymes or digestive ferments, with the production of a number of intermediate products, each product being simpler than the preceding one. Thus, we have what we call intermediary metabolism, meaning a series of gradual, progressive decompositions. In some cases it is possible to trace out these processes step by step, from organ to organ, or from tissue to tissue, and we find a row of bodies intermediary between protein and urea, for example, each one of the substances so formed corresponding to Sir Michael Foster's steps in this flight of stairs, until the bottom step is reached. The ultimate result, so far as heat, for example, is concerned, is essentially the same whether the oxidation is what we might call an explosive decomposition with direct formation of the ultimate products, or whether it is a slow or gradual process, with liberation of heat at each step in the breaking down of the materials. In many of these intermediary steps, transformations are so slight that the amount of heat resulting is very small. If we take, for example, the disaccharide maltose ($C_{12}H_{22}O_{11}$) which by hydrolysis is broken down into two molecules of the monosaccharide dextrose ($C_6H_{12}O_6$), we find in this process of hydrolysis that only about 3.3 calories result. If, however, dextrose is burned up in the tissues of the body at one step, or in the laboratory, to its ultimate products, carbon dioxid and water, we have a relatively large amount of heat produced. The point to be emphasized is, that in all these chemical processes occurring in the body heat is liberated, and, as already stated, they are in the main oxidations which are effected through the influence of oxidizing enzymes or some other kindred means of activating oxygen.

The great supply of heat energy needed by the living body to maintain its normal temperature comes from these oxidative processes. The heat produced in the body is expressed as calories. The small calorie, or gram degree unit of heat, may be defined as the quantity of heat necessary to raise one gram of water one degree centigrade in temperature, while the large calorie, or kilogram calorie, is the quantity of heat necessary to raise the temperature of one kilogram of water one degree. In other words, the large calorie is one thousand times larger than the small calorie. It is generally stated that a man of average body weight and activity produces and gives off about 2,500,000 small calories of heat per day. This would mean 2500 large calories of heat. This heat comes obviously from the physiological oxidation of the food materials taken into the body, namely, the proteins, fats, and carbohydrates. These food materials may be burned or oxidized outside of the body, and the heat which they yield can be measured directly. Such a combustion or oxidation is ordinarily carried out in the laboratory in a bomb calorimeter under high oxygen pressure, and it is by such a method of combustion or oxidation that the heat value of the different foodstuffs is estimated. If a definite amount of a pure carbohydrate, such as starch or sugar, is burned with oxygen in a calorimeter, it is found that 1 gram of carbohydrate yields on an average 4100 calories, or 4.1 large calories. In other words, the 4.1 large calories represent the combustion equivalent of a gram of carbohydrate, which in turn is a measure of the amount of potential energy of this particular form of foodstuff which would be available within the body for the production of heat or for the supply of energy for the cells or tissues. This means obviously that the end-products in the oxidation of carbohydrate are the same in the body as those formed by combustion outside the body. If a definite amount of fat is burned with oxygen in a calorimeter, it is found on an average that 1 gram of fat yields 9300 calories or 9.3 large calories. This figure, like the corresponding figure obtained by the combustion of a carbohydrate, is a measure of the amount of potential energy which this form of foodstuff is capable of furnishing for the production of heat or energy in the body, since fat, like carbohydrate, burns to the same end-products by oxidation in the body as in combustion outside the body. In considering the heat value of protein as utilized in the body, we find that the end-products of its oxidation in the organism are carbon dioxid and water, together with urea and some other nitrogenous waste products. In other words, the breaking down of protein in the body is not as complete as is the combustion of protein outside of the body. If a gram of protein, for example, is burned with oxygen in a calorimeter, it yields on an average 5778 calories. When burned in the body, however, the nitrogen of the protein molecule is eliminated in the form of urea, and there are also certain other nitrogenous products, all of which have heat value of their own. If it is assumed, as is quite proper for such a purpose, that essentially all the nitrogen of the protein broken down in the body appears eventually in the excreta as urea, and that one-third gram of urea results from the breaking down of one gram of protein, we may deduct the heat value of this amount of urea from the combustion equivalent of one gram of protein, with the result that the average heat value to the body for one gram of protein is about 4100 calories, or 4.1 large calories.

By such methods the heat values of protein, carbohydrate and fat, or the amount of potential energy which these foodstuffs contain, available for supplying the energy needs of the body, may be estimated. The average values usually made use of by physiologists are as follows:

1 gram of protein = 4100 calories, or 4.1 large calories. 1 gram of carbohydrate = 4100 calories, or 4.1 large calories. 1 gram of fat = 9305 calories, or 9.3 large calories.

It is obvious from these statements that, knowing the composition of any given food, it is possible to calculate its heat value or potential energy. Since our food is in a sense fuel to supply the energy of the body, we may also speak of these values as fuel values. In the table already presented, showing the chemical composition of some common food materials, there is given a column of figures showing the fuel value per pound of the different food materials expressed in calories. It is to be remembered, however, that heat value or fuel value of a food is not the only factor to be considered in determining food value. The nitrogen content, which in a sense is a measure of the amount of protein present, is likewise essential. Further, there are many minor factors connected with our food material which must be given consideration, since many of such minor factors are of importance, and sometimes of great importance, in determining nutritive value.

As it is very difficult, in many cases at least, to determine directly the amount of protein contained in any foodstuff, it is the custom to estimate the amount of protein by a determination of the amount of nitrogen contained in the food material. As has already been stated, protein on an average contains 16 per cent. of nitrogen. Consequently, multiplying the percentage of nitrogen contained in a foodstuff by the factor 6.25 gives the amount of protein. It is easy to see that such an estimate is not always quite correct, since it assumes that all the nitrogen in foodstuffs is in the form of protein. This is not always the case, but in a majority of foodstuffs the larger percentage of nitrogen is protein nitrogen, and consequently this method is, on the whole, fairly satisfactory.

Knowing the composition of foods, especially their content of protein and their fuel value, the next factor to consider is, how far foods are capable of being utilized by the body. It is frequently stated that the body is not nourished by what is eaten, but rather by what is digested and absorbed, for not everything that is eaten is available for the needs of the body. There is always the question of utilization, of the relative digestibility. Physiologists determine the degree of utilization of any given food by a simple feeding experiment, either on man or with animals, as the case may be. The food is carefully weighed and analyzed, its content of protein or nitrogen and fat determined, and then the solid excrement is collected for a given period, say of twenty-four hours, while the diet in question is being taken. The excrement is then subjected to chemical analysis and its content of nitrogen and fat determined. In this way, by comparison of the intake of nitrogen and fat and their output in the solid excrement, the percentage utilization of nitrogen or protein and of fat can be ascertained.

For 130 days.

Subject.	Utilization of nitrogen, per cent.	Utilization of fat, per cent.
1	89	98
2	90	98
3	89	97
4	88	97
5	88	97
6	88	98

In the above table are the data connected with six human subjects, where a feeding experiment was continued for 130 days, with a view to determining the utilization of both nitrogen and fat. These figures show at a glance that in this particular experiment the fat of the food was much more completely absorbed and utilized than the nitrogen or protein food. In other words, these subjects during four months utilized practically between 97 and 98 per cent. of the fat fed. Of nitrogen, however, only 88 to 90 per cent. was utilized. This relatively low utilization of nitrogen, however, was due to the character of the food, which was largely vegetable in its nature. It is a well-understood fact that the easily digestible animal foods, such as meat, eggs, milk, etc., are absorbed or utilized up to even 99 per cent. In vegetable foods, however, the utilization is less complete, as in the above table. This difference in the utilization of vegetable protein is not due to any specific peculiarity of the vegetable protein, but is to be attributed to the general character of vegetable foodstuffs with their large content of indigestible cellulose which renders the digestion of the protein relatively difficult. It is not uncommon to find with some vegetable foods a loss through the feces of 25 per cent. of the protein ingested. Here, however, care in the preparation of the food counts for considerable. Thorough cooking and careful preparation of such vegetable products result frequently in raising the degree of utilization.

In the two following tables are shown the utilization of fat and of nitrogen in a long series of experiments made upon dogs, each period covering ten days. Here the food fed was essentially the same in composition as regards the content of nitrogen or protein and fat; but as the experiment progressed the proportion of vegetable protein was increased, so that in the later periods the food was almost entirely of vegetable nature. It will be observed that in the utilization of fat there was no particular difference in the various periods. Thus, in dog 5, the utilization of fat varied only from 96 to 98 per cent. This holds true for nearly all the dogs. In some one period there may be seen a decided change, but in general the utilization of fat was essentially the same for a given dog throughout the individual periods. In the utilization of nitrogen or protein, however, the result was different. In most cases, as the experiment progressed, there is to be observed a falling off in the utilization of nitrogen. Thus, in dog 4, while in the first two periods of ten days each the utilization of nitrogen varied from 94 to 95 per cent., in the later periods it gradually fell as the proportion of vegetable food was increased. While some exceptions may be found with the different dogs, yet in a general way this same tendency is seen throughout the experiment.

UTILIZATION OF FAT IN PERCENTAGES.

Periods.	Dogs. 1	2	3	4	5	12	13	15	17	20
1	97	96	93	97	97	96	96	98	98	95
2	96	96	98	98	98	94	95	97	98	95
3	98	97	97	99	96	97	97	98	94	98
4	98	96	97	97	96	94	95	98	97	97
5	96	..	94	98	97	95	95	98	97	96
6	97	98	94	98	97	96	94	97	96	97
7	97	98	98	97	96	93	95	97	98	96
8	..	..	98	96	96	96	93	97		
9	..	..	98	97	98	..	97	98		
10	..	..	98	97	98					
11	..	..	97	92	97					
12	..	..	97	97						

UTILIZATION OF NITROGEN IN PERCENTAGES.

Periods.	Dogs. 1	2	3	4	5	12	13	15	17	20
1	95	91	92	94	91	91	90	93	92	91
2	92	94	94	95	93	90	92	96	92	87
3	91	92	90	91	88	89	86	95	89	91
4	90	85	90	92	91	82	83	91	83	93
5	90	82	88	92	86	85	84	96	91	90
6	86	87	89	83	86	89	87	94	91	86
7	87	87	90	83	87	83	88	90	93	91
8	..	..	90	83	84	81	89	89		
9	..	..	89	87	92	..	87	89		
10	..	..	93	85	94					
11	..	..	93	81	86					
12	..	..	89	92						

While the amount of nitrogen contained in the solid excrement represents mainly undigested or unabsorbed protein, the amount of nitrogen contained in the urine represents, on the other hand, the amount of protein which has been burned up in the body or metabolized. Hence, collection of the urine during a given period and determination of the content of nitrogen is the means by which the physiologist determines the extent to which the protein food or the protein of the body tissues is metabolized. The amount of nitrogen in the feces represents mainly undigested protein. The amount in the urine represents protein which has been utilized or metabolized. If the urine of twenty-four hours shows on analysis, a content of 16 grams of nitrogen, this means that there has been broken down in the body during that period $16 \times 6.25 = 100$ grams of protein material. It is to be remembered, as previously stated, that protein contains on an average 16 per cent. of nitrogen, and as practically all the nitrogen coming from the breaking down of protein in the body is excreted through the urine it is apparent that the amount of nitrogen contained in the urine in a given period, multiplied by the factor 6.25, gives the amount of protein broken down or metabolized in the body during that period.

If the total nitrogen of the food intake during a given period amounts to more than the total nitrogen of the feces and of the urine for the same period, it is plain that the difference must represent nitrogen or protein which has been stored up in the body. On the other hand, if the nitrogen of the urine and feces during a given period amounts to more than the nitrogen of the food ingested during that same period, then it is evident that the body must be losing nitrogen from the breaking down of tissue protein. In other words, under these last conditions the body is not being fed sufficient food material to meet the needs of the body, and hence the body is compelled to draw upon its own tissues to supply its needs. By methods such as these it is possible to strike a balance which will determine whether the body is taking on or losing nitrogen. If the balance is even, the body is in what is termed nitrogen equilibrium, which means that it is receiving in the food as much protein nitrogen as it is metabolizing in the body and eliminating in the excreta. If there is a plus balance in favor of the food, it is clear that the body is laying on or storing protein. If, on the other hand, the nitrogen balance is a minus one, the body must plainly be losing protein. During the period of growth or in the recovery from wasting diseases, such as fevers, etc., the body tends to store protein, and under such conditions the balance obviously would be in favor of the food nitrogen. Throughout adult life, however, the diet is usually regulated, consciously or unconsciously, under normal conditions, so that nitrogen equilibrium is generally maintained through relatively long periods of time.

A person may be in nitrogen equilibrium and yet gain or lose in body weight. This may be due to a lack of carbon equilibrium, to a gain or loss of fat, for example, although it may equally well be due to changes in the content of water in the tissues of the body. In body equilibrium, body weight obviously would remain practically stationary, although it is plain that under such conditions there might be a lack of nitrogen equilibrium. In carbon equilibrium the total carbon of the excreta, namely, carbon dioxid in the expired air, the carbon of the organic substances contained in the urine and in the solid excrement would be balanced by the intake of carbon with the food. Plainly, a person may lose or gain in carbon, while the nitrogen is essentially in equilibrium. Theoretically, one may have a water equilibrium or an equilibrium of inorganic salts, but such conditions have little physiological significance. The three important conditions to be considered are nitrogen equilibrium, carbon equilibrium, and body equilibrium. Carbon equilibrium can be determined by the use of a respiration chamber, in which the subject under examination lives under conditions where the total quantity of carbon dioxid given off from the lungs and through the skin can be accurately determined. In such an apparatus, or air-tight chamber, air is drawn through the apparatus by means of a pump, the total amount of air passing through being measured by a gasometer. Definite fractions of the air obviously can be drawn off from time to time and analyzed for carbon dioxid. The urine and fæces are collected and analyzed, while at the same time the intake of food is measured and the content of protein, fat and carbohydrate determined. In this way it is possible to make not merely a balance of the intake and output of carbon, but a complete balance may be struck in which both carbon and nitrogen balances can be estimated, as well as changes in body weight. Under ordinary conditions adult persons usually live so that they maintain a general body equilibrium; that is, the ingesta of all kinds are balanced by the corresponding excretions, the individual maintaining practically constant body weight.

We now come to what constitutes a very important and significant property of protein food, viz., that protein or nitrogen equilibrium can be maintained at different levels of nitrogen intake. If a person is in a semifasting condition, eating each day a much smaller amount of protein food than the needs of his body demand, it would naturally be expected that if the intake of protein food is considerably increased the body would hold on to the larger portion of the increased protein, but such is not the case. Experiment shows that under such conditions where the body is practically living in large measure on the protein of its own tissues, the extra protein fed is at once metabolized in the body, the nitrogen at once eliminated, instead of being stored up in the tissues, and nitrogen equilibrium is established at a higher level. In other words, protein food actually tends to increase metabolism in the tissues. This property is usually spoken of as the "specific dynamic action" of protein. This stimulation of the metabolic processes of the body shows itself not only in increasing the output of nitrogen, signifying increased breaking down of protein, but it is accompanied likewise by an increased metabolism of the fats and carbohydrates of the body.

Date.	Body weight, kilos.	Nitrogen of the food, grams.	Nitrogen excreted, grams.	Nitrogen balance grams.
Nov. 6	65.4	2.69	8.31	− 5.62
7	65.4	2.69	5.37	− 2.68
8	65.1	2.69	5.71	− 3.02
9	65.3	2.69	4.88	− 2.19
10	65.0	2.69	4.32	− 1.63
11	64.9	2.69	4.25	− 1.56
12	64.9	2.69	4.47	− 1.78
13	64.6	2.96	4.88	− 1.92
14	64.4	2.96	4.30	− 1.44
15	64.3	2.96	4.75	− 1.79
16	64.4	2.96	4.36	− 1.40
17	64.4	2.96	4.13	− 1.17
18	64.4	2.96	4.35	− 1.39
19	64.4	2.96	4.32	− 1.36
20	64.4	2.96	4.22	− 1.26
21	64.0	2.96	4.06	− 1.10
				−31.31
22	64.1	4.02	4.22	− 0.20
23	64.4	4.02	4.35	− 0.33
24	64.4	4.02	4.21	− 0.19
25	64.4	4.02	4.40	− 0.38
				− 1.10
26	64.2	8.24	6.56	+ 1.68
27	64.4	13.45	8.67	+ 4.78
28	64.4	13.66	10.54	+ 3.12
29	64.0	13.45	11.10	+ 2.35
30	64.2	13.24	12.83	+ 0.41
Dec. 1	64.2	13.24	11.70	+ 1.54
2	63.9	12.61	12.00	+ 0.61
				+14.49
3	64.0	22.93	16.24	+ 6.69
4	63.9	22.41	21.47	+ 0.94
5	63.9	22.41	23.10	− 0.69
6	63.6	23.35	23.12	+ 0.23
7	63.9	23.04	22.82	+ 0.22
8	63.8	22.62	22.86	− 0.24
				+ 6.15

In the above table are given the results of a series of observations made by Siven on himself. The table shows body weight, the amount of nitrogen in the daily food, the amount of nitrogen excreted through the urine and feces, and the nitrogen balance, for every day through a period covering more than a month. The amount of non-nitrogenous food taken is not specified, but it was not excessive in quantity. During the first period from November 6 to 21, the amount of protein food ingested daily was very small, namely, 2.9 grams of nitrogen, equal to about 18 grams of protein. During this period it will be observed that the nitrogen excreted daily through both the urine and feces amounted to over 4 grams per day, which means that the body was breaking down protein tissue equal to between 25 and 30 grams. The daily nitrogen balance during this period was a minus one, amounting to more than a gram of nitrogen per day during the latter part of the period. At the same time, it will be observed that the body weight was practically constant during the last ten days. On November 22, the intake of nitrogen was increased to 4 grams, equal to 25 grams of protein food. Under these conditions the body weight remained as before and the nitrogen excreted was slightly in excess of the nitrogen ingested. The minus balance was a very small one, equal to only a third of a gram of nitrogen per day. On November 26, the protein food was increased in amount, so that the nitrogen ingested was 8.24 grams. On this day there was a decided plus nitrogen balance. On the following days it is to be noted that each increase in the amount of nitrogenous food ingested is accompanied by a corresponding increase in the amount of nitrogen excreted, accompanied on most days by a plus nitrogen balance. Yet it is to be observed on December 5 and December 8, when 22 grams of nitrogen were consumed daily, there was still a minus nitrogen balance.

The main point, however, to be emphasized in connection with these data is that there is a certain low limit of protein which just suffices to maintain nitrogen equilibrium. Beyond this point, up to the limit of the capacity of the body to digest and absorb protein food, there is always a tendency for nitrogen equilibrium to be maintained. Thus, it is seen in these experiments that with an intake of 13 grams of nitrogen, the plus nitrogen balance is just as large, or even larger, than with an intake of 23 grams of nitrogen daily. Further, it is to be noted that with increase of protein food to the limit recorded in these experiments as on December 5 and 6, body weight tends to diminish rather than increase. This is in harmony with the statement already made, that protein food tends to increase not only the rate of protein metabolism, but likewise tends to increase the rate of carbon metabolism or the metabolism of fat and carbohydrate. Plainly, one may ask the question, What level of protein or nitrogen intake is most desirable for the maintenance of the best condition of health? Increasing the amount of protein food appears to result in increasing the rate at which proteins, fats and carbohydrates are broken down, and is not accompanied by any appreciable storing of protein for the future needs of the body. Further, since increase of protein food is accompanied by a corresponding increase in the excretion of nitrogenous waste products, it is obvious that under such conditions considerable energy must be wasted in the excretion of this added waste. Unless the body in some manner derives special benefit from the non-nitrogenous part of the protein molecule, there would seem to be no good reason for the daily consumption of these larger amounts of protein food far beyond what is necessary to maintain nitrogen equilibrium.

In this connection it is well to emphasize the effect of non-nitrogenous foods on the rate of protein metabolism. Both fats and carbohydrates tend to lower the rate at which protein undergoes metabolism; or, in other words, they protect the protein of the food and of the tissues. If an animal, for example, is brought into a condition of nitrogen equilibrium on protein food alone, the addition of a non-protein foodstuff, such as fat or carbohydrate, reduces considerably the amount of protein necessary to maintain nitrogen equilibrium. Fats and carbohydrates therefore are protein-sparers, and this is one of the important points connected with their nutritional value.

In the following data from experiments made by Voit on dogs, it is to be observed that the addition of 150 grams of fat to the 1500 grams of meat fed resulted in a sparing effect on protein or flesh metabolized amounting to 38 grams. In the second experiment, where only 500 grams of meat were fed, the addition of 100 grams of fat resulted in the sparing of 36 grams of protein. The radical point of difference in the two experiments is the amount of protein ingested. As has already been stated, protein food stimulates protein metabolism; it likewise accelerates the metabolism of non-nitrogenous matter. Consequently, the sparing or protecting effect of the fat is most conspicuous where the intake of protein is relatively small. In other words, 100 grams of fat taken in conjunction with 500 grams of meat exercises practically as great a sparing effect on protein as 150 grams of fat when fed in connection with 1500 grams of meat.

Food.		Flesh.	
Meat, grams.	Fat, grams.	Metabolized, grams.	On the body, grams.
1500	0	1512	−12
1500	150	1474	+26
500	0	556	−56
500	100	520	−20

When carbohydrate is added to a meat diet, there is at once a saving in the decomposition of protein, as shown in the following figures covering an experiment of two days:

Meat, grams.	Sugar, grams.	Flesh metabolized, grams.
500	200	502
500	0	564

Without the sugar there were 64 grams of protein metabolized in excess of the protein fed, but addition of the 200 grams of sugar caused practically a saving of all this with formation of essentially a nitrogen balance.

The sparing of protein by carbohydrate is greater than by fats; a fact of considerable dietetic importance, and it is well illustrated by the following experiments taken from Voit:

Food.		Flesh.	
Meat, grams.	Non-nitrogenous food, grams.	Metabolized, grams.	Balance in the body, grams.
500	250 fat	558	− 58
500	300 sugar	466	+ 34
500	200 sugar	505	− 5
800	250 starch	745	+ 55
800	200 fat	773	+ 27
2000	200–300 starch	1792	+208
2000	250 fat	1883	+117

In considering the results of this experiment, it is to be remembered that the calorific or fuel value of fat as compared with carbohydrate is as 9.3 to 4.1. In spite of this fact, it is clearly evident that the sugar and starch are far more efficient than fat in protecting protein. Thus, with the income of 500 grams of meat and 250 grams of fat, the body of the animal lost 58 grams of protein; while with a like amount of meat and 300 grams of sugar the body not only saved the 58 grams of protein, but in addition stored up 34 grams, showing a plus balance to that extent. Again, with 2000 grams of meat, the plus protein balance with the starch was considerably greater than the plus balance with 250 grams of fat.

It is plain from the foregoing that on a mixed diet of protein and non-nitrogenous food, the proportion of the latter may be increased and that of the former decreased to a marked degree without causing a loss of protein tissue from the body. As already stated in other connections, food fulfils two distinct purposes. It furnishes the material for the formation of new living matter, or the replacement of that which is continually being lost. In addition, it furnishes a supply of energy for the work done by the various cells of the body, the contraction of the muscles, the secretion of the glands, the discharges of the nerve cells, etc. For the first function, protein is absolutely needed, and perhaps it is the only form of food that is needed; but for the second function, that is, the energy requirements, this may be met by any of the three energy-yielding foodstuffs, *i. e.*, carbohydrates, fats, or proteins, especially by the carbohydrates. If the supply of non-protein material is relatively large, then, as we have seen, the amount of protein food can be lowered to a certain minimum, which is plainly required for the construction of the living materials of the cells and tissues of the body.

Part II.

It is plain from what has already been stated that the two non-nitrogenous foods, fat and carbohydrate, play a very important part in nutrition, because of their ability to protect in a measure the integrity of tissue protein. When it is remembered that a diet of pure protein, such as meat or eggs, must be excessive in quantity in order to meet the energy requirements of the body and that the stimulating action of protein food serves to whip up body metabolism, it may be appreciated at full measure the great physiological saving which results from the addition of carbohydrate and fat to the daily diet. The establishment of nitrogenous equilibrium is made possible at a much lower level by the judicious addition of these two non-nitrogenous foodstuffs. Further, it has been made clear that a certain minimum amount of protein food is necessary for the construction and maintenance of the living protoplasm of the cells and tissues of the body.

We may next consider whether there is any truth in the old-time belief that protein or nitrogenous foods are essential for muscular activity; or in other words, that the source of muscular energy is to be found in the metabolism of protein material. This view, which was originally enunciated by Liebig, was based on the principle that proteins were plastic foods; that is, they had to do with the construction of the protein tissues, and that consequently protein must be the material burned up or oxidized when muscles are active. Experiments carried on by many physiologists have shown, however, quite conclusively that protein is certainly not the sole source of muscular energy. One of the early experiments bearing on this question was carried out by two German physiologists, Fick and Wislicenus. These two experimenters ascended a high mountain, and knowing the weight of their bodies, it was possible to estimate how much work was done in ascending this mountain to a height of nearly 2000 meters. Prior to the ascent, the food consumed by these men was entirely non-nitrogenous, and during the climb of eight hours, and for six hours afterward, the food was likewise non-nitrogenous. The urine was collected and the nitrogen determined, from which it was easy to estimate the amount of protein that had been destroyed. It was found that the energy contained in the protein broken down was quite inadequate to account for the work done, and their calculation left out of consideration entirely the amount of work done by the heart and respiratory muscles.

Experiments made upon dogs working in a treadwheel and upon men performing work while in a respiration chamber have all given data showing that the energy of the muscular work performed was far in excess of the heat energy of the protein oxidized during the period or periods. Further, experiments made upon soldiers and others while resting and performing long marches have shown that there is no distinct increase in the excretion of nitrogen after muscular exercise. The only conditions under which muscular work appears to be accompanied by an increased excretion of nitrogen is when the subject is taking a very small amount of non-nitrogenous food, or when the work performed is very excessive. The facts apparently are that the muscle is a protein machine for the accomplishment of work, but in the ordinary performance of work there is apparently no greater wear or tear of the machinery; that is, no greater tissue waste, than when the muscle is in a resting condition.

Whenever a person performs muscular work, it is obvious that some material must be burned up in order to provide the energy, and since this material is apparently not protein, it is plain that it must be some non-nitrogenous material. Experiment shows that when muscles are made to work there is at once an increased output of carbon dioxid, accompanied by an increased consumption of oxygen. This is well illustrated in the following experiment taken from Benedict and Carpenter:

	CO_2 eliminated, grams.	O_2 absorbed, grams.	Heat produced, calories.
Man at rest, sleeping	23	21	71
Man at rest, sitting	33	27	97
Man at rest, standing	37	31	114
Man during severe work	248	213	653

In the above experiment the effect of severe work, as compared with the other conditions, is very marked, both in the amount of carbon dioxid (CO_2) eliminated and in the amount of oxygen (O_2) absorbed. It is perfectly clear from these results that the output of carbon dioxid, which means the breaking down of carbonaceous material, must vary enormously during the day with variations in the muscular activity of the body. The one important factor influencing the oxygen and carbon dioxid exchange in the lungs, *i. e.*, the extent of the respiratory interchange is muscular activity. In muscular work respiration is increased in frequency and in depth. The volume of air exchanged in the lungs during severe labor may be increased sevenfold, while the oxygen consumption and carbon dioxid excretion are frequently increased seven to ten times. The following figures may be given as an

Form of work.	Oxygen consumption in cubic centimeters.			Respiratory quotient.
	Total.	After deducting value for rest.		
		Total.	For each kilo of moving weight.	
Standing at rest	263.75	..	..	0.801
Walking on a level . . .	763.00	499.25	8.990	0.805
Climbing	1253.20	989.45	17.819	0.801

added illustration, showing the effect on oxygen consumption of walking on a level and climbing, the subject being a man of 55.5 kilos body weight. The figures given are values for one minute. These data simply afford another striking illustration of the influence of muscular activity upon the exchange of matter in the body, and confirm what has already been stated many times that oxidation, especially the oxidation of fat and carbohydrate, by which large quantities of heat are set free, easily convertible into mechanical energy, is a primary factor in those metabolic processes by which the machinery of the living man is able to work so efficiently.

It is plain from what has been said that muscular work as carried on under ordinary conditions calls for carbohydrate and fat in the daily diet rather than for protein. Protein metabolism is not increased by work, providing sufficient non-protein food is being eaten. This means plainly that excessive eating of protein food, meats and kindred products, is not necessary for the doing of muscular work. There must obviously be sufficient protein in the daily diet to meet the needs of the cells of the body to keep the machine in good working order, but the energy called for in even excessive muscular work, is derived ordinarily and most advantageously from carbohydrates and fats.

A mixed diet, one which contains protein, fat and carbohydrate, together with salts and water, is the most beneficial to the body and one which accords with physiological experience. As stated many times, a certain amount of protein food is needed for the construction and maintenance of cell protoplasm; fats and carbohydrates are required to supply the energy needs of the body. Fats and carbohydrates may be substituted one for the other in some measure, but carbohydrates, for many reasons, constitute the larger proportion of the non-nitrogenous food with most peoples. This is due not alone to the fact that carbohydrates are relatively easy of digestion and oxidation, but also because of the abundance and consequent cheapness of carbohydrates as a class. A study of the dietary habits of peoples throughout the world has shown that in most countries carbohydrates are usually present in the daily diet in amounts five to ten times greater than the quantity of fat. From an energy standpoint, as already explained, one part of fat is the equal of 2.3 parts of carbohydrate, such as sugar or starch. Consequently, in the replacing of starch by fat, or *vice versa*, they must be substituted one for the other in isodynamic amounts; that is, 1 gram of fat will take the place of 2.3 grams of sugar, so far as the yield of energy is concerned.

The average daily diet with its heat value, advocated by the celebrated physiologist Voit, of Germany, is as follows:

	Grams.	Calories.
Protein	118	483
Fats	56	520
Carbohydrates	500	2050
		3055

Ranke, on the other hand, recommended a diet composed as follows:

	Grams.	Calories.
Protein	100	410
Fats	100	930
Carbohydrates	240	984
		2324

Moleschott, another authority often quoted, gave the following data as representing an average daily diet:

	Grams.	Calories.
Protein	130	533
Fats	40	372
Carbohydrates	550	2275
		3180

From these statements it is apparent that the authorities quoted considered that man needs approximately 100 to 130 grams of protein food a day, with sufficient fat and carbohydrate to make a fuel value ranging from 2300 to 3100 calories. It is obvious, however, that the calorific value of the daily food, so far as the physiological needs are concerned, must vary with the degree of physical activity. Where a large amount of muscular work is performed there is need for a corresponding increase in the non-nitrogenous foods, and since, as before stated, carbohydrates are both cheap and easily digestible, the increase usually comes from this class of foods.

A study of the table showing the chemical composition of some common food materials given on page 369 shows at once the advantages of a mixed diet for meeting the needs of the body for protein and total energy. Assuming the Voit standard to represent the daily needs of the adult, namely, 118 grams of protein with a total fuel value of 3053 calories, it is apparent that animal food, such as meat, would by itself be quite impossible for a steady diet. As fresh beef contains 22 per cent. of protein, it would be necessary for a person to eat 500 grams, or a little more than a pound, of beef to obtain the needed 118 grams of protein, but the fuel value of one pound of beef is only 540 calories. Consequently, in order to obtain the necessary 3000 calories, at least six pounds of beef would be required, or six times the amount of protein food really needed. This, plainly, would be physiologically undesirable and exceedingly uneconomical. If, on the other hand, bread with a fuel value of 1395 calories per pound, macaroni with 1665 calories per pound, or rice with 1630 calories per pound, are used to replace the larger portion of the meat, a mixture can be obtained much more advantageous as a daily diet.

In other words, almost any single food, if eaten in sufficient quantity to supply the nitrogen or protein requirements of the body, will give either too little or too great fuel value. A typical animal food, such as meat or eggs, when eaten in such amount as will furnish the necessary nitrogen or protein, fails to furnish more than a fifth of the fuel value required. As a rule a diet made up solely of vegetable foods, consumed in such quantity as to furnish the necessary protein, means the consumption of much more carbohydrate or total fuel value than the body really needs. There are, to be sure, certain vegetable foods, apparent from the table of food compositions, which may advantageously be used for supplying both the nitrogen and energy requirements. Practically, however, most people are accustomed to obtain their supply of proteins, fats and carbohydrates from both animal and vegetable foods. It is a fact well appreciated by physiologists that the mechanism of digestion and nutrition as a whole should not be subjected to undue strain. Consequently, the danger of consuming too large amounts of any one class of foods is just as serious as the danger of not consuming enough to meet the real needs of the body. The protein of the day's diet may well come from meat, milk, rice, bread, potatoes, and other vegetables, thereby introducing along with the nitrogen, quantities of carbohydrate and fat by which the protein requirement and the body requirement can both be met without consumption of an undue quantity of any one of the several classes of foodstuffs.

The two following tables, giving the average food consumption of peoples in Sweden and Finland, are well worthy of study as showing first the different foodstuffs made use of during a single week, the distribution of the protein in the form of vegetable and animal products, as well as the amounts of fat and carbohydrate with total fuel values for a week, from which is calculated the average daily consumption per individual.

SWEDISH—PER WEEK.

Food.	Total amount, grams.	Protein, grams.	Fat, grams.	Carbohydrate, grams.	Calories.
Rye flour	450.0	51.8	9.0	315.0	1,588
Wheat flour	275.0	33.0	4.1	198.0	985
Scotch barley	315.0	36.2	4.7	223.6	1,109
Oatmeal	210.0	27.3	12.6	138.6	797
Peas	630.0	144.9	12.0	330.8	2,062
Potatoes	3.2	41.6	3.2	435.2	1,985
Skimmed milk (liter)	4.55	159.3	31.9	227.7	1,883
Margarine	185.0	1.1	157.3	1.1	1,472
Fresh meat	340.0	57.8	34.0	...	553
Salt pork	255.0	28.1	140.3	...	1,420
Salt fish	250.0	30.0	30.0	...	402
Salt	139.0				
Pepper	1.0				
Tubers	200.0	2.4	0.4	16.0	79
Vegetables	500.0	0.8	0.1	4.0	21
Bread	4760.0	366.5	61.0	2222.9	11,192
Total	...	980.8	501.5	4112.9	25,548
Per day	...	140.1	71.6	587.6	3,650

FINLAND—PER WEEK.

Food.	Total amount, grams.	Protein, grams.	Fat, grams.	Carbohydrate, grams.	Calories.
Scotch barley	420	48.3	6.3	298.2	1,479
Barley flour	700	80.5	10.5	497.0	2,464
Oatmeal	220	28.6	13.2	145.2	835
Peas	280	64.0	5.4	147.0	914
Cheese	385	138.6	25.0	23.1	895
Butter	60	0.4	51.0	0.4	478
Roast beef	300	51.0	30.0	...	490
Pork	210	21.0	105.0	...	1,065
Suet	84	0.3	83.2	...	775
Salt fish	1050	115.5	73.5	...	1,157
Potatoes	1365	27.3	2.1	285.6	1,302
Cabbage	90	1.2	0.3	7.2	39
Syrup	40	0.4	...	29.6	124
Bread	3990	459.9	74.9	2809.8	14,105
Total	...	1037.0	480.4	4242.7	26,122
Per day	...	148.1	68.6	606.1	3,732

It is interesting to note in the two series of observations that the peoples in both countries derived the larger part of their protein from the vegetable kingdom, only a small amount coming from meat, though in Finland a relatively large proportion of protein came from cheese and from salt fish. The chief source of protein, however, in both countries in these observations was bread. Again, it is to be observed that the daily protein consumption per individual was high, 140 to 148 grams. The daily fuel value was likewise high, 3650 calories and 3732 calories.

By observations such as these, made in many countries and under different conditions of life, work, etc., so-called dietary standards have been adopted. These standards are more or less generally assumed to represent the requirements of the body for food. In Sweden, laborers doing hard work were found by some observers to consume daily on an average 189 grams of protein, 714 grams of carbohydrate, and 110 grams of fat, with a total fuel value for the day's ration of 4726 calories. In France, it is stated by a prominent physiologist that the ordinary laborer working eight hours a day must have 135 grams of protein, 700 grams of carbohyrate, and 90 grams of fat daily, with a fuel value of 4260 calories. In England, weavers were found to consume daily 151 grams of protein, with carbohydrate and fat sufficient to make the total fuel value of the day's ration equal 3475 calories. Observations of this character, which might be multiplied indefinitely, may suffice to give an idea of the average food consumption of European peoples doing a moderate amount of work.

In our own country very extensive observations have been made, especially by the office of the experiment station in the Department of Agriculture, under the leadership of the late Professor Atwater. For a period of ten years, from 1894 to 1904, dietary studies of the actual food consumption of people of different classes in different parts of the United States were made on about 15,000 persons—men, women, and children—as a result of which certain standards have been adopted, indicating the so-called food requirements of persons under different conditions of life and work. These standards vary from 100 to 175 grams of protein per day, with a total fuel value ranging from 2700 to 5500 calories. Some of the foregoing statements are brought together, in tabulated form, in the following table:

Subjects.	Protein consumed daily, grams.	Total fuel value of daily food, calories.
Swedish laborers, at hard work	189	4726
Russian workmen, moderate work	132	3675
German soldiers, active service	145	3574
Italian laborers, moderate work	115	3655
French laborers, eight hours' work	135	4260
English weavers	151	3475
Austrian farm laborers	159	5096
American subjects.		
Man with very hard muscular work	175	5500
Man with hard muscular work	150	4150
Man with moderately active muscular work	125	3400
Man with light to moderate muscular work	112	3050
Man at "sedentary" or woman with moderately active work	100	2700

These figures by no means represent the maximum food consumption. Thus, with lumbermen in the Maine woods, it was found by the United States Department of Agriculture that the intake of protein food averaged 185 grams per day, per individual, with a total fuel value of 6400 calories. The tendency has been to assume that figures such as the above, which are merely an expression of the dietetic habits of people, show the actual food requirements of persons under different conditions of life and work. This, however, is an assumption which, while it has met with more or less general acceptance, may be questioned as being strictly logical. Such data are indeed interesting and important as giving information regarding dietary customs and habits, but there seems to be no logical reason for assuming that such data represent the actual food requirements of the body. As stated by another: "Food should be ingested in just the proper amount to repair the waste of the body; to furnish it with the energy it needs for work and warmth; to maintain it in vigor; and, in the case of immature animals, to provide the proper excess for normal growth, in order to be of the most advantage to the body." Other physiologists, like Voit, have clearly emphasized the general principle that the smallest amount of protein, with non-nitrogenous food added, that will suffice to keep the body in a state of continual vigor, is the ideal diet. Any habitual excess of food over and above what is really needed to meet the actual wants of the body is not only uneconomical, but may be distinctly disadvantageous. Mankind has always been guided in dietary matters by appetite; that is, by a conscious desire for food and the desire for special kinds of food. But man is a creature of habits; he is quick to acquire new ones, and he is prone to cling to old ones when they minister to his sense of taste. Yet everyone knows that it is quite easy to acquire new habits in matters of diet as in other things, and it is difficult for the physiologist to see how habits and cravings can constitute reliable indices of true physiological requirements.

There would seem to be no reason why physiological experiment cannot be applied to a study of this general question of the true food requirements of the individual. This is especially true of the protein requirement, since it is plain, from what has been stated, that variations in activity, work performed, and matters of that kind, do not call for material increase in the intake of protein food as it does in the consumption of non-nitrogenous foods. The very way in which protein foods behave in the body makes one question the necessity or desirability of their excessive consumption. The fact that nitrogen equilibrium can be established with a relatively low nitrogen intake and that the eating of larger amounts of protein food is followed by a corresponding increase in nitrogen excretion renders one skeptical of the real value of this larger intake of nitrogenous food. If protein food—in the larger amounts—is so important for the body, why should there be such rapid decomposition and excretion of the larger part of the contained nitrogen?

Careful observations have been made upon fasting people, in some cases where fasting has continued as long as thirty days, the income being solely water. In three somewhat notable cases the daily excretion of nitrogen through the urine was determined and recorded. Such data are shown in the accompanying table, in the cases of Breithaupt, Cetti, and Succi. In Succi's case the daily average loss of nitrogen, from the 11th to 15th day, was 5.11 grams; from the 16th to 20th, 5.3 grams; from the 21st to 25th, 4.7 grams; and from the 26th to 30th, 5.3 grams. A daily loss of 5.3 grams of nitrogen means the burning up of 33 grams of protein, or a little more than an ounce. It is to be noted from the table that in all three of these cases the amount of nitrogen eliminated on the 6th day was essentially the same—practically 10 grams. This would mean the breaking down of 62.5 grams of protein. Can we assume from this that men of the body weight here recorded need 62.5 grams of protein food per day to make good the loss? Obviously, this conclusion would not be justified. Much would depend upon the condition of the body tissue,

NITROGEN EXCRETION THROUGH THE URINE.

Day of fasting.	Breithaupt (59.9 kilos), grams.	Getti (56.5 kilos), grams.	Succi (62.4 kilos), grams.
0	13.0	13.5	16.2
1	10.0	13.6	13.8
2	9.9	12.6	11.0
3	13.3	13.1	13.9
4	12.8	12.4	12.8
5	11.0	10.7	12.8
6	9.9	10.1	10.1
7	..	10.9	9.4
8	..	8.9	8.4
9	..	10.8	7.8
10	..	9.5	6.7

as to the amount of contained fat and carbohydrate. In the complete absence of food, the body must necessarily feed upon itself, and in fasting the degree to which protein is broken down will depend upon the amount of available fat in the tissues. If the body fat has been largely used up, then it is plain that all the energy needs of the body must come from the breaking down of protein. In other words, the feeding of fat and carbohydrate would naturally diminish the breaking down of protein, so that quite likely these three subjects were eliminating more nitrogen, *i. e.*, breaking down more protein in the 6th and 10th days of fasting, than they would if they were consuming a certain proportion of fat and carbohydrate.

A large number of experiments upon various classes of people in my own laboratory, covering long periods of time, have led me to believe that for a man weighing 70 kilograms, or 154 pounds, there is required daily 60 grams of protein food to meet the needs of the body. These are perfectly trustworthy figures, with a reasonable margin of safety, carrying perfect assurance of being fully sufficient to supply all the physiological demands of the body; an amount equal to practically one-half the Voit standard for a man of this body weight. In this connection we must emphasize the fact that no general statement can be made applicable to mankind in general, but there must be due consideration of the size and weight of the individual structure. In other words, a man of 170 pounds body weight has more protein tissue to nourish than a man of 130 pounds body weight, assuming that the difference in weight is not due to difference in adipose tissue. Putting the matter concisely, I believe that adults require daily 0.85 gram of protein per kilogram of body weight.

SIXTY GRAMS OF PROTEIN ARE CONTAINED IN

	Fuel value, calories.
One-half pound fresh lean beef, loin	308
Nine hens' eggs	720
Four-fifths pound sweetbread	660
Three-fourths pound fresh liver	432
Seven-eighths pound lean smoked bacon	1820
Three-fourths pound halibut steak	423
One-half pound salt codfish, boneless	245
Two and one-fifth pounds oysters, solid	506
One-half pound American pale cheese	1027
Four pounds whole milk (two quarts)	1300
Five-sixths pound uncooked oatmeal	1550
One and one-fourth pounds shredded wheat	2125
One pound uncooked macaroni	1665
One and one-third pounds white wheat bread	1520
One and one-fourth pounds crackers	2381
One and two-thirds pounds flaked rice	2807
Three-fifths pound dried beans	963
One and seven-eighths pounds baked beans	1125
One-half pound dried peas	827
One and eleven-twelfths pounds potato chips	5128
Two-thirds pound almonds	2020
Two-fifths pound pine nuts, pignolias	1138
One and two-fifths pounds peanuts	3584
Ten pounds bananas, edible portion	4600
Ten pounds grapes	4500
Eleven pounds lettuce	990
Fifteen pounds prunes	5550
Thirty-three pounds apples	9570

To make quite clear just what such a standard of 60 grams of protein food means, attention may be called to the above table, in which are given the amounts of different kinds of foodstuffs which will yield 60 grams of protein, and also the fuel value of such quantities of the foods in question. From this table it is seen that the daily protein requirement of 60 grams can be obtained from one-half pound of uncooked lean meat, from three-fourths pound of halibut, from one pound of uncooked macaroni, from five-sixths pound of uncooked oatmeal, or from two quarts of milk, etc. Plainly, however, these quantities of foods must be reinforced by addition of non-nitrogenous foods, in order to bring the fuel value to the required amount. Lastly, it is to be emphasized that no definite figure can be given regarding the amount of carbohydrate and fat required in the daily diet, or the total fuel value, since this is dependent upon the degree of activity of the body. In a general way, it is perfectly clear that the sedentary individual doing little muscular work needs far less of non-nitrogenous foods, than the individual who is doing vigorous work. My own opinion is that the average man leading an ordinary life, involving only an average amount of muscular activity, needs in his daily food a total fuel value of not more than 2800 calories.

The importance of protein food in the nutrition of the body has been repeatedly emphasized. Stress has been laid upon the quantity of protein necessary to meet the needs of the body, but in addition it is important to recognize the existence of different nutritive values for the individual proteins. In the animal and vegetable kingdoms are many different forms of protein all superficially alike, but with a certain degree of individuality. The casein of milk is different from the albumen of the egg; the gliadin of wheat flour differs from the gelatin of connective tissue; the protein of nuts has a chemical nature different from that of the cereals; and so we might make comparison of hundreds of different proteins scattered throughout the animal and vegetable kingdoms, all of which are used in some degree at least as foods. While they are superficially alike, they are distinctly unlike in their chemical structure. This difference in structure implies a difference in physiological behavior. The blood of one species of animal, with its contained albumens, cannot be injected into the blood-vessels of another species without causing harm or even death. Albuminous substances which are foreign to the blood of a given species may act as a poison when introduced directly into the circulation. We, as human beings, however, are feeding upon a mixed diet of proteins from all sources and utilizing these different forms of protein to our own advantage. The domestic animals as sheep and cattle, grazing side by side in the same pasture, eat exactly the same food under the same conditions and yet each species has in its own fluids and tissue proteins peculiar to itself. This implies a process of transformation or synthesis, by which individual proteins may be transformed into other quite different forms of protein.

Native proteid

Protoproteose	Heteroproteose
Deuteroproteose	Deuteroproteose
Peptone	Peptone
Amino-acids	Amino-acids

Protein foods, when eaten, are subjected to the action of gastric and pancreatic digestion, reinforced by such ferments or enzymes as are present in the intestine, and as a result the native proteins are broken down by successive stages through proteoses and peptones into the comparatively simple bodies known as amino-acids, by a process perhaps analogous to the scheme here presented. As representing these amino-acids we have relatively simple crystalline nitrogenous substances, such as glycocoll, leucine, proline, tyrosine, arginine, lysine, tryptophane, etc.

It is apparently with these amino-acids that the body has to deal in the construction of its own tissue proteins. These amino-acids are recombined by processes of selection through synthesis to form organized proteins of the kind characterizing the different tissues of the body. Just how this synthetical construction is effected we do not know, but it is assumed that the several amino-acids are combined one with another, thus gradually building up the complex protein molecule. Probably such amino-acids as are not needed to make the required proteins are burned up to supply energy. The fundamental idea, therefore, is that from the supply of amino-acids furnished to the body by the digested food proteins, the ones needed are selected to construct the particular tissue proteins of the animal, so far as these are required for growth or tissue repair. The other point necessary to be emphasized from the standpoint of nutrition, especially with reference to food values, is that the individual proteins are chemically unlike, and consequently have different nutritive values.

In the laboratory it is possible to break down protein artificially through hydrolysis with boiling acids, in which case the molecule is broken apart into its component amino-acids. These can be separated and the amounts determined. In the following table the composition of eight distinct proteins is given, showing the percentages of amino-acids contained in them. A study of this table shows at once what a striking difference there is in the chemical nature of these individual proteins. Casein of milk, for example, as contrasted with the gelatin of bone, contains no glycocoll, while the latter contains 16.5 per cent. of this substance. Casein contains 10.5 per cent. of leucine, while gelatin contains 2.1 per cent. Casein has in it 11 per cent. of glutaminic acid, while gelatin has less than 1 per cent. of this amino-acid. Casein contains tryptophane, while gelatin has none of this substance. Again, contrast casein with its 11 per cent. of glutaminic acid with the vegetable products hordein of barley and gliadin of wheat, both of which contain over 35 per cent. of this particular amino-acid. These eight examples are merely illustrations of the differences which exist in the chemical nature of the individual proteins, and since physiological behavior depends in large measure upon chemical constitution, it is quite apparent that the individual proteins must possess different nutritive values.

Amino-acids.	Gelatin, bone.	Casein, milk.	Excelsin, Brazil-nut.	Hordein, barley.	Phaseolin, bean.	Gliadin, wheat.	Glutenin, wheat.	Leucosin, wheat.
Glycocoll	16.5	0	0.6	0	0.55	0	0.89	0.94
Alanine	0.8	0.9	2.33	0.43	1.8	2.0	4.65	4.45
Valine	1.0	1.0	1.51	0.13	1.04	0.21	0.24	0.18
Leucine	2.1	10.5	8.7	5.67	9.65	5.61	5.95	11.34
Proline	5.2	3.1	3.65	13.73	2.77	7.06	4.23	3.18
Phenylalanine	0.4	3.2	3.55	5.03	3.25	2.35	1.97	3.83
Aspartic acid	0.56	1.2	3.85	+	5.24	0.58	0.91	3.35
Glutaminic acid	0.88	11.0	12.94	36.35	14.54	37.33	23.42	6.73
Serine	0.4	0.23	0	..	0.38	0.13	0.74	
Tyrosine	0	4.5	3.03	1.67	2.18	1.2	4.25	3.34
Arginine	7.62	4.84	16.02	2.16	4.89	3.16	4.72	5.94
Histidine	0.40	2.59	1.47	1.28	1.97	0.61	1.76	2.83
Lysine	2.75	5.8	1.64	0	3.92	0	1.92	2.75
Ammonia	..	..	1.8	4.87	2.06	5.11	4.01	1.41
Tryptophane	0	1.5	+	+	+	+	+	+
Cystine	..	0.06	0	+	..	0.45	0.02	
	38.61	50.42	61.09	71.32	54.27	65.81	59.66	50.32

Feeding experiments made upon animals have shown that certain proteins contain all the amino-acids necessary for maintenance and growth; such proteins are frequently spoken of as "adequate" proteins. Others suffice for maintenance; that is to say, they furnish material for the energy needs of the body and for the repair of tissue waste, so that an animal fed upon such proteins does not lose body weight, but they are quite inadequate for the purposes of growth in young animals. Lastly, there are still other proteins which, when fed as the sole protein food, are insufficient both for maintenance and for growth; such proteins are frequently designated as "inadequate" proteins. Gelatin is a good illustration of a protein of the latter type. It is readily digested and ultimately undergoes oxidation in the body, its energy being utilized; but owing to its lack of certain amino-acids, such as tryptophane and tyrosine, it is quite incompetent to maintain life; it is not able to maintain nitrogen equilibrium; it is not able to supply the nitrogenous material needed for the repair of the tissues of the body. If, however, an animal is fed upon a diet in which gelatin is the only protein substance, it can be kept alive by adding tryptophane, cystine and tyrosine, showing that these amino-acids which are lacking in the gelatin molecule are necessary for the construction of the proteins needed by the animal system. In other words, where growth and maintenance are to be accomplished, the protein food must contain the needed amino-acids, or building stones, from which the tissue proteins are constructed.

The gliadin of wheat and rye is a protein characterized by containing a relatively large proportion of glutaminic acid and ammonia-yielding groups, with an almost complete absence of lysine and glycocoll, and very small amounts of the amino-acids, histidine and arginine. It has therefore a very unique constitution, very different from the tissue proteins of animals, as well as from most of the other proteins which are commonly present in the food of man and animals. With such a peculiar and one-sided protein, feeding experiments were carried out by Osborne and Mendel on white rats for long periods of time covering more than 500 days. Using pure gliadin as the sole form of protein food, these animals were maintained in apparent health and strength throughout the long period of the experiment. There was no impairment of the capacity to produce healthy young and to nourish them, one female giving birth to a litter of four at the end of 178 days on the gliadin food mixture. These young rats were nourished satisfactorily by their mother during the first month of their existence, so far as could be judged by comparison of their increase in weight with that of normally reared rats. The results of this experiment leave no doubt that here where there was such a marked renewal, or new formation, of body tissue, very large in proportion to the original weight of the mother animal, there must have occurred a synthesis not only of the building stones or amino-acids deficient in the protein intake, but likewise of tissue and milk components of great variety and complexity which were completely missing in the special food intake that had formed the sole food of the mother during several months.

There is another side to this experiment, however, that must not be overlooked, as it is full of significance. At the end of thirty days three of the young rats were removed from the mother and placed upon diets of milk and other foods more nearly approaching the normal, while the fourth animal was allowed to remain in the cage with the mother, whose sole source of nutriment was the gliadin food mixture. The three removed animals manifested a normal growth on their new dietaries, but the fourth animal, kept with the mother, began to evince a failure to grow at about the period (30 days) when young rats are wont to depend upon extraneous food for nourishment. In other words, the young animal, forced to depend upon the gliadin food mixture in place of the milk of its mother, showed a failure to grow on the diet upon which the mother had not only been maintained, but had actually produced young and secreted milk sufficient in quantity and quality to induce normal growth in her offspring. Young rats fed on a single protein of a different type, aptly termed an adequate protein, such as the casein of milk, glutenin of wheat, etc., will show steady growth up to say 300 days, at which age they normally grow very little more. A young gliadin rat, on the contrary, fed solely on gliadin as the protein part of its food, can be maintained for long periods, 500–600 days, but there is no growth to speak of. The youthful appearance of animals thus maintained without growth corresponds in every respect, so far as external characters go, with the size rather than the age of the animal. The power of growth in these cases, however, is not lost, but is simply held in abeyance. Thus, in one experiment, reported by Osborne and Mendel, with gliadin as the sole protein of the diet, after 276 days of stunting, changing the diet to milk powder in place of gliadin, growth began at once and continued up to 314 days.

The animal body can be maintained so long as the protein supplied is not deficient in certain individual amino-acid groupings or building stones, but there is some other factor involved when the problem of growth is considered. Given a diet composed of some pure protein, suitable in character, reinforced with fat and carbohydrate, the animals will grow up to a certain point and then for week after week they remain practically stationary. Maintenance may be perfect, health and strength seemingly quite normal, but there is no growth. The diet, so far as its content of nitrogen and fuel or energy value are concerned, may be more than adequate. Increasing the volume of the food, even when fully eaten and digested, brings no result. The animal remains stunted. If now, without any other change in the diet, a minute portion of dry milk powder, for example, is added to the food, growth at once recommences, and this happens even though the animal has been stunted for a relatively long time. The milk powder is too small in amount to give any added fuel value, and it may be freed from all traces of protein without causing any loss in efficiency. There is plainly some accessory factor here which is directly concerned in the growth function.

This suggests that in the nutrition of the body, certainly in growth, there are factors involved which are wholly unrelated to energy supply or to the amount and character of the protein intake. In a general way, it may be said that the needs of the body for food are met by so many grams of protein or nitrogen per day and so many calories or kilogram degree units of heat. The chemical processes concerned in nutrition have for their main object the breaking down of these complex materials of the food into simpler fragments, with liberation of the contained energy; a series of progressive chemical decompositions in which large molecules are broken down into smaller ones, and these in turn into still smaller ones, until finally the ultimate end-products are reached which are cast out of the body. Now, however, we see the necessity of giving some heed to the *character* of the protein introduced into the food supply, and the necessity of recognizing the physiological distinction between growth and maintenance as two distinct phases of nutrition. Finally, we have forced upon us the experimental evidence that there are certain accessory factors concerned in nutrition, which in the process of growth at least are of fundamental importance.

As Professor Hopkins, of England, has recently written, it is possible that what is absent from artificial diets and supplied in such addenda as milk and tissue extracts is of the nature of an organic complex (or of complexes) which the animal body cannot synthetize. But the amount which seems sufficient to secure growth is so small, that a catalytic or stimulating function seems more likely. Stimulation of the internal secretions of the thyroid and pituitary glands, which are believed on very suggestive evidence to play an important part in growth processes, can be legitimately thought of. On the other hand, the influence upon growing tissues may be direct.

Here, then, we have formulated an important principle, viz., that growth in the young animal is not so much a question of the amount of the food supply, as it is of the presence or absence of the specific accessory factors which, directly or indirectly, govern and control the process. Indeed, I am inclined to make the statement somewhat broader and to say that the processes of nutrition, as a whole, are in large measure dependent for their proper working upon the presence of accessories which hitherto have gained little or no recognition. As a recent writer has said, "the animal body is adjusted to live either upon plant tissues or the tissues of other animals, and these contain countless substances other than the proteins, carbohydrates and fats."

To give force to my argument and at the same time to introduce an additional fact, let me refer briefly to the disease known as beri-beri and other forms of peripheral neuritis, as this may also serve to emphasize how small may be the actual amount of a specific substance which determines proper physiological functioning. Beri-beri, a disease long known in China, Japan, the Philippines, and other localities where rice constitutes a prominent part of the dietary of the people, has always been associated with rice, so that for a long time this staple article of food has been considered as a causative factor in this disease. During recent years, however, many medical men have claimed that the connection between rice and beri-beri was wholly an indirect one, the low protein intake of peoples subsisting mainly upon rice being the real cause of the disease, a hypothesis which seemingly received support at the time of the Japanese-Russian war. At this period the Japanese army and navy were placed on a ration practically indentical with that of European nations, American canned meats being the main source of the added protein. Strange to say, after this increase in nitrogen intake beri-beri, which up to that time had been widely prevalent throughout the navy particularly, began to wane and soon largely disappeared. This fact has been brought forward by many writers as proof of the greater efficiency of a high protein intake and conversely of the deleterious effects of a low protein diet on the power of resistance to disease. Today we may use this incident as an illustration of how mankind is prone to err in drawing conclusions from observations, and how frequently the unimportant is magnified and made the nucleus of the argument, because by chance it fits in with preconceived ideas. As a matter of fact, the high or low protein intake in itself has no causal relation whatever with the disease known as beri-beri; the etiology of this disease is to be sought for in the rice itself. As the work of Eykman and others has shown, however, it is not rice in general that causes beri-beri, but rice that has been prepared in a certain way. It is only the polished rice, *i. e.*, rice that has been cleaned of its cuticle and outer layers by a process of milling that is harmful.

It has now been demonstrated experimentally that beri-beri in man and polyneuritis in fowls, when associated with rice as a diet, are due to the removal of the outer portion of the grain or the pericarp. Prior to 1910 beri-beri was very common throughout all the public institutions of the Philippines; also among the Philippine troops of the United States Army. Since that date, when an Executive Order was issued by the Governor-General of the Philippine Islands prohibiting the use of polished rice in all public civil institutions, beri-beri has practically disappeared.

The recent work by Funk suggests that the essential ingredient in the rice polishing is an organic base; a substance plainly of great physiological importance. A daily diet in which polished rice is the main ingredient may prove deleterious simply because it fails to provide this important accessory compound that resides in the outer layers of the rice berry, or which might be supplied by certain other foods, such as beans, meat, etc. The smaller amount of nitrogen furnished by the rice diet is merely an incident having no connection whatever with the cause of the disease. As illustrating the physiological importance of little things in diet, it is only necessary to state that the amount of this organic, nitrogenous substance in rice is probably not more than 0.1 gram per kilogram. Further, as Funk has shown, the curative dose of the active substance is very small; a quantity which contains only 4 milligrams of nitrogen is sufficient to cure pigeons in which polyneuritis has been induced by feeding polished rice.

Finally, let us turn to another phase of protein metabolism, or more particularly that form of metabolism which has to do with the production of uric acid, a substance which plays an important part in connection with diseases, such as some forms of rheumatism, gout, etc. In the tissues of the body, and as common constituents of our foodstuffs, are certain so-called purin bodies, such as hypoxanthin, xanthin, adenin and guanin, to which may be added caffein, thein and theobromine; the three latter occurring only in food. The purins present in the tissues of the body exist there both free and combined. In the combined form they are present as parts of the nucleins and nucleoproteins which are found in the nuclei of all cells, and hence are present in all tissues. Xanthin and hypoxanthin as free bases are conspicuous in muscle tissue and in many organs of the body, while adenin and guanin are especially noteworthy as components of nucleic acid, which when combined with protein forms the nucleins and nucleoproteins so conspicuous in every tissue cell. Guanin and adenin are amido bodies, and in the metabolic and other changes which take place in the tissues both of these bases lose their amido group and are converted into xanthin and hypoxanthin, each more highly oxidized than the base from which it is derived. The xanthin and hypoxanthin thus formed, in their further passage through the organism, are in large measure oxidized to uric acid. Theobromine, caffein and thein are methyl purins, and when these compounds are taken into the system they first lose their methyl groups and are then transformed into xanthin and hypoxanthin, with the possiblity of ultimate conversion into uric acid.

So far it has been implied that the uric acid formed in the body comes from the transformation of free and combined purins taken with the food—exogenous purins—and from the purins set free in the tissues—endogenous purins. In the early history of metabolic studies bearing on uric acid production—or more exactly uric acid excretion through the urine—it was thought that the amount of uric acid was dependent solely upon the quantity of protein food eaten. This, however, was soon shown to be incorrect, for while it was found that on a diet rich in meats and kindred products there seemed to be a relationship between the output of nitrogen and uric acid, thus suggesting that the amount of uric acid formed was directly dependent upon the extent of protein metabolism, it soon became apparent that this relationship held good only when flesh foods were taken. With vegetable foods, or with animal foods such as eggs, milk, etc., where, as we now know purins are almost wholly absent, protein metabolism may be at a very high level with a corresponding increase in the output of urea, while the excretion of uric acid remains relatively low. In other words, the factor above all others that influences the output of uric acid through the urine in healthy subjects is the presence or absence of free and combined purins (nucleins) in the daily food. Let me quote a few results bearing on this point taken from our own laboratory experiments:

First subject, 70 kilos body weight. High protein, purin-free diet composed of 9 eggs, 2 quarts of milk, 200 grams of bread, and 75 grams of butter. This day's diet contained 138 grams of protein, 191 grams of fat and 241 grams of carbohydrate, with a total fuel value of 3300 calories. On this diet the total output of nitrogen through the urine was 20.11 grams, while the output of uric acid amounted to only 333 milligrams.

Second subject, 66.6 kilos body weight. Moderate protein diet, fairly rich in purins. The day's ration consisted of lamb chops, sweetbread rich in nucleins, beefsteak rich in free purins, potatoes, asparagus, peas, bread and coffee (containing caffein). Total output of nitrogen through the urine amounted to 16.43 grams, while the output of uric acid was 623 milligrams.

In these two cases the point to be emphasized is that the excretion of uric acid is in no sense proportional to the extent of protein metabolism, to the extent of nitrogen excretion, but is governed primarily by the amount of purins present in the food. Thus, the second subject, with sweetbread and other purin-containing articles in his diet, excreted almost twice as much uric acid as the first subject, although the latter showed a far higher total nitrogen output; *i. e.*, a higher level of protein metabolism in harmony with the larger protein intake.

If the purin-containing food is increased largely in amount, then the uric acid excretion is found to run parallel. Thus, a *third subject* fed for a day largely on shad roe, rich in nucleins, excreted on that day 1.37 grams of uric acid; the total nitrogen output through the urine being 21.1 grams, only a little more than was excreted by the first subject. The uric acid excretion, however, on the shad roe diet was more than four times that of the subject on the purin-free diet.

Fourth subject, 74.4 kilos body weight. Without food of any kind for two days. On the second day, the excretion of total nitrogen through the urine amounted to 9.5 grams, while the output of uric acid was 376 milligrams.

In this case it is to be noted that the excretion of uric acid was essentially the same as that shown by the first subject on a high protein, non-purin diet. Obviously, these figures for uric acid on a purin-free diet and during fasting represent more or less accurately the amount of endogenous uric acid, excreted during the twenty-four hours, from the disruption or breaking down of the tissue nucleins, and other tissue components. To measure the endogenous uric acid accurately however, requires a somewhat different method, namely, a procedure that excludes any disturbance of the general metabolism of the body, such as undoubtedly occurs during fasting. The best method is to determine the excretion while the subject is living on an adequate diet, but one that is absolutely purin-free, say a diet of pure fats, carbohydrates and eggs. Potatoes, white bread and milk, however, contain only traces of purins, so that they, too, may be added to the diet without danger. By such forms of feeding experiments on men, notably those by Burian and Schur, it has been demonstrated that the endogenous purin excretion varies considerably with different individuals. It does not, however, vary with differences in the character of the diet, provided the latter is purin-free and is adequate in amount.

Obviously, whenever it is desired to diminish the amount of uric acid floating about in the body, a diet mainly vegetable in nature, or one which is free from meat and other substances containing purins (free or combined), should be followed. In such cases only uric acid of endogenous origin will be present.

CHAPTER XIV.

DERMATOLOGY.

By GEORGE M. MacKEE, M.D.

In the small space that has been allotted for the purpose of considering the abnormal conditions of the skin, it will be possible to touch only upon the diseases and conditions that are most important to municipal public school nurses and dental hygienists. For this reason it will be necessary to omit a lengthy discussion of the anatomy, physiology and hygiene of the normal skin, and it will be impossible to deal with affections which for the most part are of cosmetic importance, as well, also, as the rarer forms of skin diseases. A general knowledge of the cause and diagnostic characteristics of the skin diseases most likely to be encountered in school, dental and municipal work is, however, of no little importance.

Anatomy and Physiology of the Skin.[1] It should be understood that the skin consists of two parts—the outermost, thin layer (epidermis) and the deep, thick layer (derma). The *derma* contains the blood-vessels, the lymphatic vessels, the sweat and oil glands, the nerves and the hair bulbs. It should be remembered that such appendages of the skin as the hair and nails are formed in the derma by an invagination of the epidermis. The derma is a supporting structure and is composed of connective and elastic tissues.

The *epidermis* is protective. It is composed of several layers of cells known as epithelial cells. They are produced by a division of the cells of the lowermost layer and gradually force their way to the surface. At first they are oblong in shape, but as they progress toward the surface they become flattened and of a somewhat horny consistence. The outermost layer of cells is known as the horny layer. These cells are being constantly shed as new ones take their place. The epidermis can reproduce itself, so that its destruction is not followed by a scar. When the derma is destroyed, however, a modified tissue takes its place. This is poorly supplied with the usual structures found in the derma, and such tissue is known as cicatricial or scar tissue.

Besides acting as a protective envelope, the skin has other physiological functions which cannot be discussed here. It might be mentioned, however, that it is important as a *respiratory* and *excretory* organ. For this reason it is advisable always to keep the skin in good condition.

[1] See Chapter I, Fig. 14.

ELEMENTARY NOMENCLATURE.

Before entering into a description of the various skin diseases it will be necessary to explain the meaning of certain elementary words that will be used over and over again in the text.

(*a*) **Lesion.**—A lesion means any disturbance in the skin. It may be a bruise (contusion), a cut (incision), a raw spot (excoriation), a swelling, an ulcer, a "pimple," etc.

Lesions are divided into:

Macule.—A macule is a spot on the skin that can be seen but which cannot be felt. It may be of any color. We usually limit the term to lesions varying in size from a pin-point or pin-head to a silver dollar. A freckle is an example of a macule.

Papule.—A papule is a small solid lesion that can be felt with the finger. It, too, may be of any color. Papules are the same as macules in size. They may be flat-topped or pointed, round, oval or square, slightly or considerably elevated. The small, hard, elevation that so often follows a mosquito bite may be taken as an example of a papule.

Pustule.—A pustule is a lesion the size of a papule, but which, instead of being solid, contains pus. The spots so frequently encountered on the face of young people and known as "pimples" are usually pustules.

Vesicle.—A vesicle is a lesion, the size of a papule, which contains a clear fluid. Such lesions when larger than a dime are called blebs or bullæ (bulla). These three lesions are often spoken of as blisters. While they usually contain clear fluid, the contents may be cloudy and even bloody (hemorrhagic).

Nodule.—A nodule is a hard swelling that is too deep, or too large to be a papule. They are usually about the size of a walnut. They may be under the skin, so that they cause very little if any elevation, or they may produce a marked elevation.

Tumor.—A tumor is really any papular or nodular lesion, but the term is usually employed to signify a swelling that is larger than a nodule. Like the nodule, it may be very little or considerably elevated.

(*b*) **Dermatitis.**—This term signifies an inflammation of the skin.

(*c*) **Erythema.**—This is a redness of the skin due to a dilatation of the bloodvessels. The word congestion is practically a synonymous term.

(*d*) **Edema.**—This is a swelling of the skin due to the liquid part of the blood (serum) passing out of the vessels into the surrounding tissues. It is usually associated with dermatitis, erythema or congestion.

(*e*) **Circinate or Annular.**—These are lesions, usually papules or macules, which assume the form of a ring. They may be produced by a lesion clearing in the center or by a circular grouping of individual lesions.

(*f*) **Gyrate.**—This term signifies an irregular outline. A gyrate patch, for instance, is formed by the coalescence of several annular or circinate lesions.

(*g*) **Patch or Plaque.**—These are palm-sized, or larger, single lesions or aggregations of individual lesions.

DISEASES OF THE SKIN.

The first group of skin diseases to be considered is that of the *parasitic affections*. These are divided into vegetable and animal.

FIG. 196.—Ringworm.

Vegetable Parasitic Affections.—**Ringworm.**—Ringworm of the skin (Fig. 196) is a very common contagious disease in children. It also frequently occurs in adults. It begins as a pin-head-sized, very slightly elevated, pale red, slightly scaly papule. This papule gradually increases in size until it attains the dimensions of a dime, a quarter or a silver dollar. As it enlarges it partially or wholly clears in the center, forming a circinate lesion. In a typical example the center of the lesion is composed of normal skin, while the margin is slightly scaly and of a pale red color. A mild degree of itching is usually present. The lesions may be multiple; more commonly, however, there is but a single ring. Occasionally there is a ring within a ring. It may attack almost any part of the body.

It should be remembered that domestic animals—cats, dogs, and cattle—suffer from ringworm, and human beings not infrequently contract the disease from contact with such animals. Fortunately the disease, excepting in the scalp, is not serious and can be easily cured.

Ringworm of the scalp is a much more troublesome malady, and merits a separate description. Here, the disease not only attacks the skin, but the roots of the hair become affected, a situation almost impossible to reach by remedial agents.

The symptoms consist of one or several round, slightly red, scaly areas ranging in size from a split pea to a dime and even to a silver dollar (Fig. 197). While usually scattered, they may combine to produce large, irregularly shaped patches. There is usually a little

Fig. 197.—Disseminated ringworm of the scalp.

itching. The most typical feature, however, is the breaking of the hair close to the scalp, leaving the remaining portion of the hair appearing as a short stump.

A typical example of ringworm of the scalp consists of a dime-sized patch of mild dermatitis (redness and scaling) and hair stumps. Occasionally, the disease will produce pus in the hair follicles and in the deeper portions of the scalp. This gives rise to a boggy swelling, but here, too, the hairs are broken off close to the scalp. The pustular form of ringworm of the scalp, after healing has taken place, may leave an area of scar tissue associated with total baldness, so that after an attack of this kind it is not uncommon to encounter multiple small areas of baldness. The disease disappears spontaneously at the time of puberty and is very rarely encountered in the adult.

Animal Parasitic Diseases.—Pediculosis.—There are three types of pediculosis, all caused by a louse (pediculus). The *head louse* produces a condition known as pediculosis capitis; the *body louse*, pediculosis corporis or vestimentorum; and the *pubic louse*, pediculosis pubis.

Pediculosis Capitis.—Here, the pediculus inhabits the hairy scalp, cementing its eggs (nits) to the shaft of the hair. The white "nits" must be carefully differentiated from flakes of dandruff. This is easily

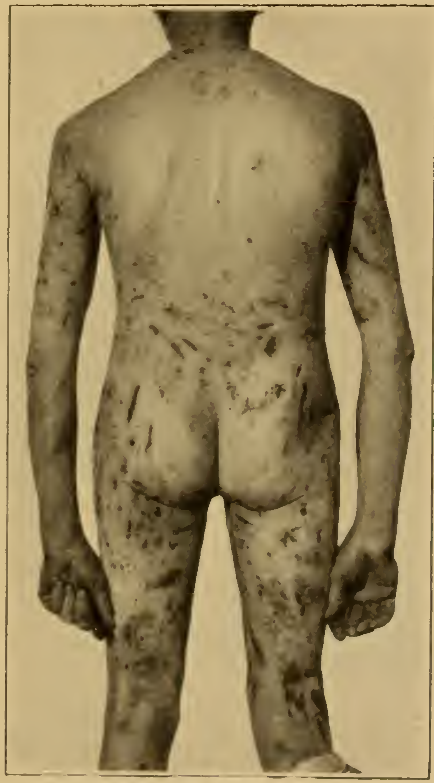

Fig. 198.—Pediculosis.

accomplished by the fact that dandruff can be readily displaced from the hairs; this is not so with the "nits." The only lesions found on the scalp are scratch-marks, blood crusts and, occasionally, pustular and crusted lesions which result from infection following the scratching. Itching, of course, is a marked feature. The affection is encountered at all time of life.

Pediculosis Corporis (Fig. 198).—Here, the pediculus, which is considerably larger than the head louse, inhabits the underclothing. The parasite itself produces no lesions upon the skin, but its bite produces considerable itching which, in turn, causes scratching. The scratching gives rise to scratch-marks, excoriations and blood crusts, with occasional pustules and crusted lesions from infection with the ordinary pus-producing bacteria. There is probably no disease that causes such intense itching and such severe scratching as does this affection. While the entire covered part of the body may be affected, the lesions are likely to be limited to the areas that are in close contact with the clothing, such as the upper back, the chest, the abdomen and the buttocks.

Pediculosis Pubis.—The pubic louse, while occasionally spreading to the armpits, chest and legs, usually is localized in the genital region.

Fig. 199.—Scabies.

The insect is found with its head in a hair follicle. The egg is firmly cemented to the hair close to the skin. The only symptoms are the severe itching and the usual results of scratching. This affection is limited, obviously, to adolescents and adults.

Scabies (Itch, Fig. 199).—Scabies, or what is known vulgarly as the itch, is a very common, contagious, animal parasitic affection in children and adults. Here, the parasite enhabits the skin. The lesions are produced by the female insect, which burrows along under the outermost layer of the skin and deposits her eggs. The first lesion, therefore, is a furrow. This is an irregular, fine, black line under the skin. The color is caused by the excreta of the parasite. The insect itself is too small to be seen with the naked eye.

The excreta, being a foreign body, produces irritation which results in the formation of a vesicle or a pustular lesion, usually the latter, which, in a few hours becomes crusted. Itching is usually intense and the skin shows evidence of scratching. As a rule the eruption begins on the hands, especially between the fingers. It then attacks the forearms, the armpits, the penis in the male and the nipples in the female. In a severe case the eruption may become quite generalized. The face and scalp, however, are never involved.

Bacterial Diseases.—Impetigo Contagiosa.—This is probably the most common skin disease of childhood. It is also frequently observed in adults. The affection is caused by the ordinary pus-producing organisms (staphylococcus and streptococcus), and is very contagious.

Fig. 200.—Impetigo contagiosa. The lesions are composed of yellowish, thick, porous crusts (honey-comb crusts). They are easily removed on account of the pus and serum underneath.

It usually attacks the face and hands, but it may occur on any part of the body.

The first lesion of the disease is a vesicle which, in a few hours, becomes a pustule. This either ruptures or is broken and the pus and serum dries and forms a yellowish-colored crust. These crusts are often very thick, but porous and light in weight, and are spoken of as honey-comb crusts (Fig. 200). It is not common to see the early (vesicular) stage of the disease. Usually, when the individual comes under observation, there are a few or many small areas of pustular or pustulocrustaceous lesions.

The disease may be primary or secondary. That is, it may be contracted directly from another individual, or it may be the result of a discharge from the nose, eye or ear. Again, it may be caused by infection from scratching, so that the disease may be secondary to such affections as pediculosis or scabies. When a lesion once develops it is likely to be spread to other parts of the body by the hands.

Acne (Fig. 201).—This is the affection vulgarly termed "pimples." It is due to the action of the acne bacillus together with the staphylococcus. At the age of puberty there is a marked development and physiological activity of the oil (sebaceous) glands of the face, which appears to favor the growth of the acne bacillus. This organism, by causing an inflammation of the sebaceous gland and duct, produces a retention of the modified secretion. This plug, with its collection of dead, black cells at its outer end is termed a comedone or "black head." The pus organisms now become active and a pustule is formed around the comedone. It will be obvious that this disease is most common at the age of puberty. It may continue throughout the period

Fig. 201.—Acne vulgaris, showing pustular lesions on the face.

of adolescence or even into adult life. It not infrequently happens, too, that the affection is first manifested years after the advent of puberty. It is probable that the acne bacillus and staphylococcus are always present in the skin, but they only become active when conditions favor their development. The circulation in the so-called flush centers of the face—forehead, chin, cheeks and nose—can be greatly modified by faulty gastro-intestinal conditions and, also, by lowered vitality of the organism as a whole and particularly of the nervous system. In adults, therefore, the indirect cause of the affection is probably some disturbance in the general health.

The disease may consist of comedones alone or is associated with papules, nodules and pustules. The latter may be small and superficial, or they may be deep-seated and as large as a finger-nail. There is usually a dilatation of the follicles ("pores") and an excessive oily secretion. The disease, if allowed to exist for a number of years, will produce considerable scarring and will otherwise seriously interfere with the maintenance of a "good complexion." While usually limited to the face, the affection may attack the shoulders, neck, back and chest. It is not contagious.

Boils.—These are due to the local and deep-seated action of the staphylococcus. It is not known whether the infection is from without or within—possibly both. In any event an individual who develops a boil will usually have several of them and a "run of boils" is considered as an evidence of impaired health. The development of a boil is manifested by a stinging pain and the appearance of a small, red spot, which upon palpation is found to be hard. (It is possible to abort a boil in this stage by the local use of poultices, an incision and other methods.) Within twenty-four to forty-eight hours a hard nodule forms which, in a few days softens, ruptures and pus is evacuated; healing, with scar formation, then occurs.

A *carbuncle* differs from a boil in being limited to one large lesion with multiple pus pockets.

Erysipelas.—This is a dangerous infectious disease due to a special variety of streptococcus. After the organism enters the skin there is a diffuse and intense redness produced, which is accompanied with some swelling (edema) which, however, may be very marked in certain locations, such as the eyelids. The disease spreads rapidly with a sharp line of demarcation, while the parts first affected undergo resolution. The disease is ushered in with a chill which is followed by a high fever. In severe cases the patient may become delirious. The germ gains entrance into the skin through wounds or abrasions. In facial erysipelas the portal of entry may be the ear, or the mucous membrane of the mouth or nose. Every case of this disease should be isolated as soon as recognized.

Diseases due to External Irritants.—A dermatitis or inflammation of the skin, when due to the external application of an irritating substance, is known as *dermatitis venenata*. There is a long list of substances that will produce a dermatitis venenata in susceptible individuals, the most common of which are:

Strong soap.	Varnish.
Turpentine.	Resinous woods.
Metol.	Dyes.
Primrose.	Sulphur.
Iodoform.	Chrysarobin.
Poison Ivy.	

Most everyone is familiar with the skin that has been poisoned with one of the poisonous members of the

Sumac Family (*Ivy*).—The eruption is composed of deep-seated closely packed, minute vesicles. This is accompanied with swelling or edema, which may be very severe around the eyes and ears. Occasionally the vesicles are large, in some cases as large as a walnut. There are, also, redness, severe itching and, perhaps, stinging and burning.

The eruption begins at the point where the skin came in contact with the plant, usually the hands (Fig. 202). It then spreads to the arms, face, and, in fact, to any part of the body.

The affection is not contagious, but it is auto-inoculable; that is, if the patient touches one of his own lesions and then touches his normal skin with the same finger, a new lesion will develop, but the disease cannot be transferred from one individual to another.

Fig. 202.—Poison ivy dermatitis. Eruption is vesicular. The skin is swollen and red. Itching is severe. Note the large blister at base of thumb.

As is well known, some individuals are very susceptible to the poisonous action of ivy, while others are absolutely immune. As a rule it is necessary to actually touch some portion of the plant to acquire the disease, but it is possible that insects may transfer the poisonous principle from the plant to the individual.

The affection is not serious and lasts but a few days, as a rule, but it may completely incapacitate a very susceptible individual for a week or two. For this reason every nurse and school-teacher should be acquainted with the ivy plant and should transfer this knowledge to school children.

The common poison ivy is a vine which may creep along the ground or cover walls and trees. At times the growth of the plant is so vigorous that it forms a bush. The main points, however, are the character of the leaves, flowers and berries. The leaves are ternate—that is, they occur in threes, at the end of a stem. The flowers bloom in June and July; they are very small, yellowish-green in color and are in clusters at the junction of the stem with the stalk. In the fall, the leaves are brilliantly red and the clusters of small green berries, which have replaced the flowers, increase in size, and assume a grayish color.

Erythema Group of Skin Diseases.—It might be mentioned that the classification used here would not pass the inspection of a dermatologist. The various groups are arranged for the sake of convenience and the classification is not in accord with that found in dermatological literature (for instance, there is a class of skin diseases known as inflammations, which includes many of the affections already described, the present group, and affections that will be described under other headings). It is to be understood that the diseases are being grouped for convenience of description and that no attempt is being made toward an accurate or scientific classification.

Erythema Multiforme.—In the text-books there are a number of affections which are given various titles according to the clinical appearance, but which we will consider under the heading of erythema multiforme. For instance, there is a condition known as *toxic* erythema, where there is a diffuse redness of the entire body, even, perhaps, of the throat and mouth, and which simulates scarlet fever. It is due either to the ingestion of poisonous material or to the formation of certain toxins in the intestines, which then enter the blood and cause a dilatation of the bloodvessels of the skin with consequent redness. It lasts for a few days and then subsides, usually without, but sometimes with, slight desquamation. It is often associated with more or less fever. It can be differentiated from scarlet fever by the fact that the erythema develops over the entire body within a few hours of the onset of the trouble and there is likely to be evidence of biliousness. There are instances, however, especially during an epidemic of scarlet fever, when it is practically impossible to differentiate between the two affections.

There is another affection known as *erythema nodosum* which consists of painful, deep-seated nodules, covered with a reddened skin. The nodules are walnut-sized and occur on the arms and legs. It is most common in young people and is supposed to be intimately connected with rheumatism. It usually runs a course of from one to three weeks.

True erythema multiforme, as its name suggests, consists of lesions of various kinds. There may be red patches ranging in size from a pin-head-sized macule to areas a foot or more in diameter. These may be perfectly flat (macular) or they may be elevated by edema. There may be vesiculation and even bullous lesions. The lesions may form various fantastic configurations—complete rings, broken rings, connecting rings, lesions within lesions, urticarial wheals, etc. The mucous membranes, particularly of the mouth, may be involved. (Fig. 203.) The disease has the same cause as toxic erythema.

Urticaria.—This disease (*hives*) is a very familiar and equally annoying affection. The lesion itself consists of what is known as a wheal. This is a papule which ranges in size from a split pea to a dime. In severe cases, instead of individual papules, there may be palm-sized or larger elevated areas. These lesions develop suddenly and are at first white, but soon become pink or red. They itch intolerably and scratching only makes them worse. They are usually transient, but

Fig. 203.—Erythema multiforme. Lesions on lip consist of swellings, blisters, and crusts. The same condition is in the mouth. On the body, there are large irregular patches of redness with here and there a blister. The lesions on the wrists and hands are red rings with a small central blister. In such lesions there is often a play of colors as seen in a rainbow.

may remain for several weeks or months. At times the skin may be so irritable that the slightest touch will produce a wheal—a condition known as dermographism (Fig. 204). The affection is often associated with erythema multiforme.

The cause of this disease is usually some disorder of the alimentary tract. Often certain articles of food, such as strawberries and shellfish, will be found as directly responsible for the trouble.

Miscellaneous Diseases.—Prickly Heat.—Miliaria or prickly heat, as it is called, is a mild inflammation of the sweat glands. The disease consists of a multitude of minute and closely crowded papules. The affection is seen mostly on the trunk, but it often attacks the arms and legs. It is very common in children, especially during the hot weather. It is usually associated with a stinging or burning sensation and sometimes with itching. The treatment consists of frequent bathing with cold water and the application of a talc powder. Sweating should be avoided.

Herpes.—The ordinary "fever sores" or "fever blisters" on the lips are good examples of herpes. The affection consists of one or more groups of small vesicles, on an erythematous base, which are usually associated with considerable itching; sometimes they are pain-

FIG. 204.—Urticaria (hives). The small lesions on lower part of back are urticarial wheals which appear spontaneously. Whenever the skin of this patient is scratched, it becomes slightly red and swollen. The letters were produced by rubbing the dull end of a pencil over the skin. These lesions do not itch and this condition is known as dermographism.

ful. The favorite locations are about the mouth (Fig. 205), the eyes, and the genitals, but the disease may affect almost any part of the body. It is not a serious affection and disappears in a few days without treatment. The affection is due to an irritation of the terminal nerves—a reflex. When the lesions are on the lips the irritation may be in the gastro-intestinal tract, or it may be in some faulty condition of the teeth. When the lesions are near the eye, the eyes themselves may be at fault, etc. To prevent recurrent attacks of herpes, therefore, it is essential that the center of irritation be detected and overcome.

Alopecia.—There are several forms of alopecia (*baldness*, or loss of hair) but space will allow of a careful consideration of only one type.

Fig. 205.—Herpes simplex. This represents the ordinary fever blisters seen on the lips.

Fig. 206.—Alopecia areata. The lesions occur suddenly and the hair falls out instead of breaking off as in ringworm. There is no redness nor scaling.

Alopecia Areata (Fig. 206).—This is an affection worthy of careful consideration, because it occurs in both children and adults, but mainly because it is so often mistaken for ringworm of the scalp. It consists of one or several dime- to dollar-sized completely bald patches. Without any warning the hair falls out in a few hours. Usually there is at first only one patch and, indeed, there may be no others. But not infrequently, within the course of a few weeks, several patches will appear. There is no redness or scaliness and no subjective symptoms. Fortunately, the hair usually grows again within a few weeks or months, although the new hair may be white. Not infrequently, however, the disease will denude the scalp and, in fact, the entire body, of hair. In such instances the hair rarely regrows.

FIG. 207.—Nevus. This is an example of the common "port-wine" birth-mark.

The differentiation from ringworm is easy, as all the manifestations are quite the opposite from those associated with ringworm. Ringworm of the scalp occurs only in children. The hair breaks off instead of falling out. There is a slow instead of a sudden development and there is an erythematous and scaly instead of the smooth white skin found in alopecia areata.

Nevi.—*Birth-marks* or nevi are, unfortunately, common affections. The nevus most commonly seen is the so-called "port-wine" mark—a dark red patch, usually seen on the face (Fig. 207). (The best treatment for such a birth-mark is either freezing with carbon-dioxid snow or applications of the ultra-violet ray by means of the Kromayer lamp. In many instances this disfiguring nevus can be entirely eradicated.) The condition is an angioma—an overgrowth of the blood capillaries of the skin. When the growth of vessels is under the skin, a circumscribed, dollar-sized, red, soft tumor is produced. These tend to disappear as the child grows older. Another type of birth-mark is the pigmented or black nevus, which is usually associated with a local overgrowth of hair.

Adenitis.—Enlarged lymphatic glands (adenitis) are caused by a variety of conditions. Tuberculosis is a common cause. Bacterial infection from the mouth, throat, teeth, ears, scalp, etc., will cause enlarged glands of the neck.

Eczema.—It is impossible to deal adequately in a small space with such a complex subject as eczema. The affection is a catarrh of the skin and may be acute or chronic.

FIG. 208.—Eczema. This is an example of infantile eczema. The skin is red and a little thickened. There is weeping and crusting, and considerable itching. There is also pus formation under the crusts. Note the white nose and lips.

Acute eczema consists of circumscribed patches or diffuse areas of edema and redness with the formation of vesicles. It is not unlike dermatitis venenata. There is usually considerable burning or stinging. In severe examples the edema may be a marked feature and "weeping" (exudation of serum) is noticeable. In some instances the eruption may even become pustular, simulating impetigo.

Chronic eczema (Fig. 208) usually occurs in patches. The skin is thickened, scaly, dull red and more or less itchy. There may or may not be vesicles. Chronic eczema may result from an acute attack or it may develop more or less insidiously. The scales are dry and harsh and are shed in flakes. The scaliness is not the shiny, micacious type seen in psoriasis. Occasionally, the skin becomes so thick and hard that painful fissures develop. This is seen especially on the hands. A characteristic feature of eczema is that the patches do not have, as a rule, sharply defined margins, but gradually fade away into normal skin.

It should be understood that there is no sharp line of demarcation between a dermatitis and an eczema. As has been mentioned, an erythema is a redness of the skin—a flushing. It is simply an increased amount of blood in the skin and may be due to many causes. Let us assume that a mild, irritating substance is applied to the skin and it produces a transient erythema. Now, if this irritation is continued, the erythema ceases to be temporary, there is a congestion and serum and white blood cells pass from the vessels into the connective tissues. In other words, there is an inflammation—a dermatitis. These conditions are well demonstrated in dermatitis venenata. Now, if the inflammation continues, all the elements of the skin increase numerically, so that the skin becomes thickened; the outpouring of serum, if the horny layer is intact, causes the formation of vesicles or, if the horny layer is absent, a "weeping." This is catarrh of the skin or eczema.

Eczema, then, is simply a reaction of the skin to an irritant. This irritant may be applied from without or it may be some poisonous substance circulating in the blood and which has been produced by faulty metabolism. Primary eczema is from the latter cause, while secondary eczema is a sequel to various forms of dermatitis, such as dermatitis venenata, scabies, pediculosis, etc.

The Infectious Exanthemata.—The infectious exanthemata are acute, febrile, infectious, self-limited conditions, associated with eruptions of the skin. We will consider only the more common of these affections.

Scarlet Fever.—The onset of scarlet fever is sudden. After an incubation period of from 3 to 7 days, the disease is ushered in with indisposition, fever, headache, vomiting and sore throat. The temperarises rapidly to from 101° F. to 104° F.; it remains high until the eruption is fully developed, when it gradually declines. The tongue is coated and shows numerous red spots—the "strawberry tongue."

The rash appears on the second day and is *first seen on the neck.* It then rapidly spreads to the face, chest, arms, legs, etc. It reaches its maximum of development about the fourth day and then gradually fades. This is followed by desquamation of the skin.

The *eruption* consists of a bright red flush with closely crowded puncta (pin-point elevations). The disease is said to be infectious for three weeks, so the patient must be isolated for this period. The affection varies markedly in severity, but it is always dangerous. Severe complications and sequelæ are common, such as affections of the eye, ear and brain.

Measles.—After an incubation period of about 10 days, the individual develops a "cold"—an inflammation of the nose, eyes and throat.

The temperature rises to 101° F. to 103° F. After about four days small red spots with a minute bluish-white center can be detected on the *mucous membrane* of the *cheeks*. About this time the *eruption begins on the neck and face* and gradually spreads downward over the entire body. The eruption consists of red macules which range in size from a pin-head to a bean or finger-nail and are irregular in outline. After the disappearance of the eruption there is a slight desquamation. An uncomplicated case runs a course of from 7 to 14 days.

Measles is not in itself very dangerous. The most common complication of the disease is pneumonia—an affection with a high mortality.

German measles is hardly anything more than a very mild case of ordinary measles.

Chicken-pox.—Chicken-pox is not a serious disease. After an incubation period of from 14 to 17 days, an eruption of umbilicated vesicles occurs on the neck and face and then over the entire body. The vesicles develop in crops about 12 to 24 hours apart, so that there are always lesions in various stages of evolution. After a few hours the contents of the vesicles become cloudy and in a few days they dry up and disappear. Occasionally a scar is produced. There is usually some itching. There is not much fever. The disease lasts about a week or ten days.

Syphilis.—This disease may be considered as the most important of all the diseases in dermatology. It is an affection which attacks individuals of all ages; a disease that can be passed from a mother to her unborn infant; a disease that is highly contagious and one that will produce the most horrible results if neglected or improperly treated.

The increase in our knowledge of syphilis has been so great in the last few years that it will be worth while to outline the history of the disease.

History.—Syphilis became known to the civilized world in 1494. It first appeared in Spain upon the return of Columbus and his crews. There is no record of the disease having existed, prior to this time, in any civilized country, but there is plenty of evidence regarding the existence of the affection in Central America, previous to the voyages of Columbus. After its first appearance in Europe, the disease spread rapidly throughout the entire world, attacking people of all classes. The disease then was much worse than it is now. This was because there was at first no adequate method of treatment and, also, because the affection was working on virgin soil—that is, it was destroying the most susceptible subjects and leaving the more or less immune individuals to produce progeny who were less susceptible. The ravages of the disease in the 15th and 16th centuries almost defy description.

No disease has ever been so carefully studied as syphilis and, although a good clinical knowledge was acquired and efficacious methods of treatment were developed, it was not until about 1895 that we accumulated definite scientific facts of great importance. About this time there occurred a chain of events well worth mentioning and which succeeded in replacing mystery by definite scientific knowledge.

Previous to 1895 Ricord, Fournier, Neisser and many other scientists had given us valuable information, but the first link in the chain of events already mentioned, was the discovery by Metchnikoff and Roux that the disease could be passed directly from man to the ape. Klingmuller then demonstrated that the well-filtered virus was harmless. But it remained for Schoudinn and Hoffmann to discover the specific microörganism, which they named the *Spirocheta pallida* or Treponema pallidum. Recently Noguchi, working in the Rockefeller Institute in New York, has succeeded in cultivating the organism.

As might be expected, the discovery of the cause of the disease has led to improved methods of treatment. To the time-honored mercury, has been added the exceedingly valuable salvarsan or "606" as it is called.

Methods of Contagion.—There is a mistaken idea among the laity that syphilis is acquired only by sexual contact. This erroneous belief has been the cause of a great deal of harm. The sooner syphilis is considered an infectious and contagious disease and the sooner it is looked upon in much the same light as is tuberculosis and similar affections, the better will it be for everyone concerned. The disease is contracted in many ways, of which sexual intercourse is but one example. The syphilitic is likely to be a constant source of danger from the standpoint of contagion. He may infect eating and drinking utensils, tonsorial instruments etc.; he may transmit the disease by kissing or even by shaking hands. Fortunately, the Spirocheta pallida lives but a few hours outside of the human body; otherwise nearly everyone would sooner or later contract the affection. The organism, fortunately, cannot penetrate the unbroken skin or mucous membrane, so that an abrasion is necessary, but this abrasion may be so small, so insignificant, as to pass unnoticed. Inoculation always takes place either in the skin, or in the mucous membrane of the mouth or genitals. There are a few exceptions to this, but they will not be considered here.

Methods of Prevention.—A syphilitic can only infect another individual when he has active manifestations of the disease and then, as a rule, only in the early periods of the affection. It is the duty of the physician to instruct the patient regarding the danger to others and to treat him in such a way as to overcome at once all active and contagious manifestations. On account of the possibility of transmitting the disease to their offspring syphilitic individuals should not marry until the disease is cured.

Dentists are in constant danger of infection, and they should always inspect the mouth for the presence of suspicious lesions. If present, they should be cauterized and the mouth rinsed with an antiseptic solution, or rubber gloves may be employed. Whenever a dentist detects a wound upon his finger he should protect it with collodion.

Instruments should be properly sterilized to prevent the carrying of the infection from one patient to another. If an individual has reason to suppose that inoculation has occurred, the development of the disease may be prevented by applying the following ointment within eight hours of the time of the infection:

℞—Calomel	160 grains
Lanoline	320 grains

This ointment must be applied before the end of eight hours and should be massaged into the area for a period of five minutes. When handling a suspicious case the ointment may be rubbed into the hands before operating. The saliva of a syphilitic is not contagious unless there are lesions of early syphilis in the mouth or throat.

FIG. 209.—Syphilis. Showing the remains of a chancre of the lower lip. Note the macular eruption on the body. This is the beginning of the secondary period. The patient had not received treatment. Note the symmetrical distribution.

Description of the Disease.—*Stages.*—Syphilis is divided into three stages, namely, primary, secondary and tertiary.

Primary Period.—After infection there is a period of incubation lasting from one to three weeks. Then, *upon the site of the inoculation*, there appears a slow-developing lesion known as a *chancre* or initial lesion (Fig. 209). It begins as a small papule which slowly increases in size until, at the end of a week or two, it assumes the dimensions of a dime. It is now considerably elevated above the surrounding surface and is very hard. The center then becomes ulcerated. After reaching its maximum of development, the lesion slowly involutes and disappears in a few weeks without much scar formation. Occasionally, there may be considerable ulceration, or, rarely, the lesion may not become an ulcerated nodule, but remain as a papule. The *chain of lymphatic glands* that drain the region are affected. Usually, there is one large gland in the immediate neighborhood of the chancre; this is known as the satellite or pilot gland.

Secondary Period.—This period represents systemic involvement. The virus after leaving the chancre passes through the lymphatic channels and enters the blood stream, by which it becomes disseminated throughout the body. Usually the first clinical evidence of secondary syphilis is the development of a *generalized adenitis*—a slight swelling of all or nearly all of the lymphatic glands of the body. This occurs from three to twelve weeks after the appearance of the chancre. A week or two after the occurrence of the lymphatic involvement there is an *eruption of red macules.* The individual lesions are not scaly, as a rule, and range in size from a split pea to twice this size. The eruption may cover the entire body or it may be limited to certain regions, such as the trunk. The macular eruption develops slowly and may disappear spontaneously in a few weeks, or the macules may become papules (Fig. 210), which may or may not be scaly. Associated with this cutaneous eruption there are usually a *sore throat* and lesions in the mouth which are known as *mucous patches* and which will be described in detail later. In addition to the features already mentioned, it is extremely common to observe a *loss of hair,* and this alopecia assumes a very definite type. The hair falls out in patches, but the involved areas are never completely bald as in alopecia areata; there are always numerous healthy hairs left in the patches, so that the scalp has a "moth-eaten" appearance.

As a rule the early secondary period of the disease is not associated with severe symptoms. There may be slight fever, anemia, sore throat, loss of appetite, etc. Usually all these symptoms tend to disappear spontaneously. In many individuals, the secondaries are so slight and so transient, as to be unnoticed and if, perchance, the chancre was in the vagina or, if for any other reason, was overlooked, the patient might not be conscious of the presence of syphilis until after the lapse of many years, when destructive skin lesions or grave and dangerous nerve or visceral manifestations demonstrate the presence of the disease.

On the other hand, especially in neglected syphilis, the manifestations of secondary syphilis may be very severe. The eruptions and symptoms already mentioned, may persist or if they were transient, they are likely to return and produce what is known as secondary relapsing syphilides. These relapsing syphilides, which usually occur in the first year of the disease, have certain definite characteristics. They are always bilateral and usually symmetrical—the same lesions on both sides of the body. They are usually limited to certain regions, such as the hands, arms, legs, trunk, face, etc., rarely, although occasionally becoming generalized. They consist mainly of raw-ham-colored, scaly papules arranged in groups and tending to produce circinate, annular and gyrate configurations. It is uncommon to have ulcerative or destructive lesions in the first year or two of the disease. This, however, occasionally happens in precocious syphilis.

Fig. 210.—Syphilis. A papular eruption in the secondary period of an untreated case. The papules are of split-pea size, scaly, and of a raw-ham color. Note the symmetrical distribution.

In severe examples of the disease there may be nocturnal headache, which denotes an involvement of the nervous system. In addition, the optic or auditory nerves may be involved.

Mucous Patch.—This will be given especial consideration on account of its interest to dentists and their associates. The mucous patch is a *superficial ulcer* ranging in size from a split pea to a finger-nail, and situated, usually, on the buccal mucosa—lips, cheeks, tongue, palate and throat. It is covered with a dirty, grayish-white membrane which, when removed, leaves a superficial excoriation. There may be but a single patch or there may be several of them (Fig. 211). Another lesion of interest to dentists is the so-called split papule. This is a papule at the corner (commissure) of the mouth, and which is partly in the skin and partly in the mucous membrane. On account of its location it is usually fissured.

All the lesions of early syphilis are rich in Spirocheta pallida and are therefore *contagious.* If, however, the skin covering the lesion is unbroken, there is no danger of contagion. On the other hand, all moist lesions of early syphilis, such as the mucous patch, the chancre, the split papule, etc., are extremely contagious. The blood of a syphilitic patient, unless obtained directly from a lesion, is very slightly if at all dangerous. The secretion and excretions, such as the saliva, need not be considered dangerous unless contaminated with the discharge from a lesion.

Fig. 211.—Syphilis. Mucous patches in the secondary period of an untreated case. The patches in this individual were of long duration and had become somewhat warty.

Tertiary Period.—There is no sharp line of demarcation between secondary and tertiary syphilis. In a general way the secondary period may be considered to end at the termination of the second year. The tertiary period, beginning at the end of the second period, lasts throughout life, providing, of course, that the disease has not been cured. Manifestations of the tertiary period may develop early in the period, or the disease may remain quiescent for months or even for many years, only to have lesions appear late in life. Tertiary syphilis is noted for its destructive skin lesions (Figs. 212 and 213) and for its tendency to produce serious involvement of the internal organs, (viscera) and the nervous system.

Tumors may develop in the brain and produce pressure symptoms; the symptoms, of course, depend upon the particular part of the brain that is involved. The entire brain may become affected, producing a condition known as paresis. Certain portions of the spinal cord may be diseased, resulting in a condition known as locomotor ataxia. The arterial system is usually more or less affected, giving rise to arteriosclerosis. In fact there is hardly any part of the organism that may not be attacked by tertiary syphilis.

Fig. 212.—Syphilis. An example of an eruption composed of ulcerating nodules in neglected syphilis of the tertiary period. Note the gyrate configuration, also the scars and pigmentation.

In the skin, tertiary syphilis is manifested by slow-developing, large, deep-seated ulcers. These ulcers are not infrequently preceded by deep-seated, soft tumors. Another type of the tertiary skin lesion is a group of deep-seated, half-dime to dime-sized, raw-ham-colored nodules, which undergo ulceration with crust formation.

Fig. 213.—Syphilis. An example of an ulcerating deep-seated tumor (gumma) in neglected tertiary syphilis.

The points to remember about tertiary skin manifestations are that the lesions tend to ulcerate and to produce scars. The color is a dark red or raw ham. There is usually a marked pigmentation. The lesions are, as a rule, unilateral—on one side of the body only—and hardly ever symmetrical. The disease at this stage very frequently attacks the bones (Fig. 214).

Instead of being ulcerative or gummatous (tumors) or nodular, the lesions may be of the squamous type (scaly), especially on the palmar surfaces of the hands and plantar surfaces of the feet. Such lesions resemble eczema, but they can be differentiated from this disease because in syphilis the patches are always sharply marginated and unilateral. In fact all syphilitic lesions are sharply marginated and they almost always tend to produce peculiar configurations—scalloped edges, gyrate and annular lesions, etc. Another point is

Fig. 214.—This shows syphilitic involvement of the bones as seen in hereditary and tertiary syphilis. The lesion consists of a thickening of the periosteum and multiple abscesses in the bones—a periostitis and an osteomyelitis.

that late syphilitic lesions tend to progress slowly, while the older parts heal—this is known as a serpiginous lesion and is quite typical of syphilis, although such lesions do occur in other rare skin affections. As a rule the tertiary lesions of syphilis are not contagious, or at least very slightly so and children born during this period may never show manifestations of the disease.

Hereditary and Congenital Syphilis.—If pregnancy occurs during the early secondary period of syphilis the disease is likely to cause the death of the fetus. If, however, a live infant is born, it will usually demonstrate evidence of congenital syphilis within a few weeks. The manifestations of congenital syphilis are a discharge from the nose (snuffles) a poorly nourished condition, sores in the mouth and an eruption of bullæ, vesicles or papules on the body. Such infants usually die within a few months in spite of treatment. If a child is born in the late secondary period, it also may develop congenital manifestations or it may escape congenital syphilis, only to demonstrate hereditary syphilis sometime during life.

Hereditary syphilis is manifested in various ways. We will mention only the most common types, any one of which, or any combination of which may occur in a given individual: Faulty mental development which may range from a slight "defective" to complete idiocy; signs of nerve involvement, such as deafness, blindness, etc.; faulty physical development—stunted growth, "box-shaped" head, "saddle" nose (bridge of nose concave instead of convex), Hutchinson's teeth, etc.

Hutchinson's teeth represent one of the most common hereditary taints. This feature consists of a central notching of the superior central incisors (Fig. 215).

Fig. 215.—Syphilis. An example of Hutchinson's teeth seen in untreated hereditary syphilis. Usually only the upper permanent central incisors are centrally notched. Here both the upper and lower central incisors have a central notching.

Besides the above hereditary manifestations there may be destructive lesions of the skin and especially of the bones—as seen in tertiary syphilis. The symptoms of hereditary syphilis may occur early in life or they may not become manifest until the individual is nearly twenty years of age.

The buccal lesions of late syphilis are of special interest to the dentist and his co-workers. These manifestations may consist of tumors (gummata), ulcers (ulcerating gummata) or leukoplakia.

Gummata.—While gummata may occur anywhere in the mouth or throat, the most common site is the dorsal surface of the tongue where they usually form a soft, circumscribed, oblong, considerably elevated, painless tumor, which, if neglected, tends to break down and produce an ulcer. Ulcerating gummata are also commonly found on or near the soft palate where the tendency is for the disease to perforate the roof of the mouth (Fig. 216). These same lesions may occur on the mucous surfaces of the cheeks, especially in the neighborhood of the mouth. Here, there is more likely to be a rather diffuse and uneven infiltration, the mucosa is thrown into folds and there is more or less ulceration.

Buccal gummata must be differentiated from tuberculosis and cancer. Both tuberculosis and cancer of the mouth are more or less painful. They both develop very slowly as compared with syphilis.

Fig. 216.—Ulcerating gumma of soft palate with perforation.

Cancer is always indurated (hard) and there is likely to be a cervical adenitis. Tuberculosis of the mouth is almost always secondary to that of the throat or lungs. Finally, there is the Wassermann test for syphilis and the therapeutic test.

Fig. 217.—Syphilitic leukoplakia. (Dr. Parounagian's patient.)

Leukoplakia.—This consists of a slight thickening of the mucosa which assumes a pearly white or pure white color. It may occur in from pin-head- to split-pea-sized areas or it may be scattered as a solid patch over the mucosa of the cheek or of the tongue (Fig. 217). Leukoplakia is not always syphilitic, as it may be due to excessive smoking or to irritation from fillings, bridges, etc. In any event leukoplakia must be considered as a preëpithelioma—a forerunner of cancer.

Syphilis also causes, at times, an atrophy of the superficial tissue of the tongue with the result that the lingual surface appears smooth and glistening. On the other hand the disease may produce a glossitis consisting of hypertrophy instead of atrophy, so that the surface of the tongue is thickened, thrown into folds and, perhaps, fissured—the so-called scrotal tongue.

CHAPTER XV.

FACTORS IN PERSONAL HYGIENE.

By C. WARD CRAMPTON, M.D.

Racial Hygiene.—The subject of hygiene is one of the most important that can engage the attention of anyone. Not personal hygiene alone, but racial hygiene, the consideration of the health, illness, birth and death of whole races of beings.

Paleontology teaches us that various forms of animals once lived on this earth and possessed it; huge mastodons and dinosaurs, and other big, strong, wonderful animals; but they have died, and their species is extinct. Those races have vanished. Something unhygienic happened. The deduction from this is that there is a possible peril to the human race.

There are signs of bad hygiene and signs of impending danger, and perhaps of partial death of the race.

Race Death.—When the environment of a race changed to such an extent that it was unable to adapt itself to the new conditions, it died. Other races survived because they were able to make some slight adaptive structural change by process of evolution, fitting themselves to the changes in environment and making further progress. They were perhaps the progenitors of some of the forms of life today.

The Present Emergency.—Today the human race is changing its environment very rapidly. Within a few thousand centuries, which is a very short time, speaking biologically, many changes have been made, one of the most important being the gradual change from rural to city life. Two hundred years ago perhaps not more than 5 per cent. of the population lived in the city. Today 45 per cent. of the people of the United States live in cities. The problem of the human race of the future is the problem of the city. Now that means bricks instead of trees, asphalt instead of brooks and fences, and the iron tramway instead of country roads and the good solid earth; in short the things that are hard, things that bruise and tear and destroy the biological soundness and vitality of humanity. Therefore city life means the relative abandonment of the hope of biological continuance. Put the whole human race in cities and it would die. It is rare to find in New York City a grandchild of a New York City man and woman. Races die in cities; the biological strain is wiped out.

The conditions that make for the racial death in cities are of the greatest concern; they are problems of hygiene and of health. They are not matters of business nor of politics nor of art; they are matters of life and death, not of the individual only but of the whole race.

The biological death of city peoples has led, of course, to the coming in of people from outside, the country people and the people from abroad, to take their places. The country boy and the country girl in the city naturally come to the top to replace those at the top that are biologically unfit. That explains why there has been no cry of racial degeneration in the United States as there has been in England and in Germany. Four or five years ago England became alarmed because it could not get soldiers of the requisite height and strength. The government was anxious for the integrity of England and for the health of Englishmen. There had not been sufficient influx of hardy lower peoples to keep the race up, because much of the biological cream of England had been skimmed and sent over to the United States. And in Germany the same thing, to a somewhat lesser degree, had happened. This is the reason why the United States is not yet alarmed over a similar condition of affairs—the racial degeneration of old American stock.

Children in Schools.—So much for the importance of general hygiene. The dental hygienist will deal with children in schools, and the child in school will be found a very different thing from a mere child. He becomes a unit, one of a hundred or a thousand. He is under the teacher, the teacher is under the principal, the principal is under the superintendent, who must, in turn, look to the Board of Education, or the school committee. The child in school is not a child, but a child in relation to all of these different things; and the hygienist, going into the school, must know where she and her work may stand in relation to the other teachers, the principal, the superintendent, and the Board of Education. She is not an independent person, not even a dental hygienist, but a dental hygienist in relation to all of these persons and the influences for which they stand. Therefore it is necessary for her to know the administrative pulse and the methods and ways of conducting school affairs. These are different in each school locality; it is for the hygienist to find them out, for she will do her best work in ways that are known to the pupils, the teachers, and the principals. Forces operating along certain lines are found in schools, which cannot be pushed aside and cut across without unnecessary difficulty and friction, but if the hygienist will move along with them in ways that are known, efficiency will be trebled. In other words, the best work will be accomplished by adjusting the work—and oneself—to existing methods. If the work is carried on in harmony with the school organization, it will have a telling effect; otherwise the hygienist in the school will be as a cinder in the eye, something foreign to it, which will cause trouble.

Teaching.—The business of the school, theoretically, is to teach; practically, it is to develop children along many lines besides the regular courses of study. There is a subtle difference between teaching and developing children. They may sound like the same thing but it is the recognition of just that subtle difference which has led to the teaching of hygiene in an entirely different way from that which formerly obtained. The old method, introduced by a group of devoted, enthusiastic and very efficient women interested in temperance as to alcohol and tobacco, was text-book instruction. Text-books, every other page filled with warnings of the dangers of alcohol and tobacco, were put into the hands of every school child. On the statute books of most of the States is a requirement to the effect that certain things shall be "taught out of a text-book, and the text-book shall be in the hands of each child." It may readily be seen that a much greater emphasis is placed upon the text-book, than upon the child. Text-book instruction has resulted in the forcing of information upon children, most of which they are unable to grasp, and which is therefore a failure.

As an illustration of the newer methods of instruction, the things which are being done in New York City will be presented briefly.

SUBJECTIVE AND OBJECTIVE HYGIENE.

Objective hygiene is the doing of things with the person or persons as an object, such as surrounding them with good conditions in the schoolroom, good light, heat, ventilation, etc. In this group also fall physical training, athletics, folk dancing, playing, recesses, and other recreations. The *hygiene* of *instruction* comes under this head. The medical inspection of the pupil is at first objective, and then, if it is to be successful at all, it leads the pupil to doing things for himself and becomes subjective.

The teaching of health laws and conditions, on the other hand, is subjective. It is the endeavor to get the child to do something for himself, to inculcate habits, to form tendencies for right action, and leave him with a lasting impression that will affect conduct.

The purpose of the hygiene of instruction is the counteracting and eliminating of health-depressing influences of school life. It is not only engaged in the endeavor to keep away bad things, but it is engaged also in the endeavor to bring good things into the school.

The earliest efforts were made toward the cure of disease when it already existed; next came the prevention of disease; and now the efforts are made toward acquiring a condition of euphoria (which means a great degree of vigor), or the ability to cast aside all disease influences.

Each of these courses has been traveled in our school work, and traces of the earlier stages are left, as the cure of disease and its prevention; but the most modern effort is toward a development of the superabundance of vigor, health and happiness of the children, far beyond the mere prevention of disease.

The hygiene of instruction is not only designed to counteract and prevent health-depressing influences of school life, but to make for stronger, more vigorous lives among the children. This method controls first, the seating of the child. The school desk is an evil of long standing in the schools. Even the dental hygienist should inform herself about it, for it will avail little to keep a child's mouth in order if he is allowed to sit at a desk which necessarily cramps him until he is crouched over, with his chest caved in and his head down and body twisted. The height of the desk should be such as to permit the child to sit straight, to lean forward without bending except at the hips, and to keep the body straight; to be able to place the hands upon the desk so that the fingers may be held properly for writing, and yet that the body may be seated against the back of the chair.

The system should require the teacher to make a note of all defects of hearing and eyesight. They are now recorded by the examining physician, and the teacher places the children found deficient in one of the front rows.

The teacher herself may be called upon to conduct examinations in sight and hearing, and in default of an efficient medical inspection system the hygienist should, if possible, induce the teacher to make the tests of eyesight and hearing herself. The following case is of interest. In the truant school there was a boy who had been adjudged a bad boy and a truant. Something about his eyes attracted attention, and he was asked to read from a book which was handed to him. It was soon found that he could not do it. Books with larger and still larger type were given him and finally a placard with letters an inch and a quarter square, and it was only by bringing this huge type within six inches of his eyes that he was able to read it. That boy was not so much a truant, or a bad boy as a blind boy, and no one knew it. If such a case can be pictured to the imagination, and the damage done, not alone to a human life but a human soul, by such stupid and almost criminal neglect could be estimated, the advisability of having some kind of hearing and vision test will be readily appreciated.

The temperature of the schoolroom should be kept between 60° and 68° F. If it is allowed to rise above 70°, it is bad for the pupils and teachers and for the efficiency of instruction, and the temper and spirits of both pupils and teachers. This may be demonstrated by a person trying to study, first in a room which has a temperature of 78°, and then in another room with temperature of 65°. The difference will be obvious.

Immobility.—There is another important point and that is immobility—that is, requiring the child to sit still. The importance of tooth massage by tooth use, the importance to the tooth of its daily work has recently been demonstrated to the writer by Dr. Fones. The rhythmic, alternate compression and relaxation occasioned by chewing or eating alternately squeezes the bloodvessels, and then allows them to expand. All tissues of the human body depend for their health upon massage of this kind. The reason that any ill health of the digestive tract exists, for instance, is because people have become sedentary animals instead of walking, running, jumping, throwing, swimming animals, and from being inactive the tissues become stagnant. The result of tooth stagnation, caused by simply swallowing foods instead of properly chewing them, is known and the same relative harm occurs to the whole body when the tissues are inactive and have become stagnant. If a child is put in school for five hours each day and required to sit still during all that time, every tissue of his body is seriously damaged. This is not theory, it is a fact. A house damaged by fire plainly shows the damage, but that done to the body can only be detected by such signs of damage as the hangdog expression, poor posture, or pallor.

To correct this the following directions are given to the teachers for use in the lower grades. "Care should be taken not to require the children to sit still for a long time. In addition to the two-minute exercises which occur three times a day, quiet or vigorous games may be used when desirable, and every hour a three-minute recess may be given in which free movement about the room and quiet conversation are allowed."

This is but a poor substitute for human child activity, but it is something that can be done, while if the children were turned loose to act like children there could be no teaching done.

"In the first and second years the children may, when necessary, place head upon the arms on the desk, close the eyes, and relax completely for a moment or two." This is one of the most human things ever seen in a classroom. Upon a signal from the teacher the children simply lay their heads down on the desk and act as if they were asleep, and it is quiet. An idea of what that means to the nervous, irritable child of the city streets can hardly be imagined. It is like a breath of fresh air.

Now follows the school-teacher's part of it.

"The children should be called to strict attention immediately following the rest periods. Before any lesson requiring severe concentrated effort, a short preliminary relaxation of this kind is most helpful and the contrast between the rest and work should be decidedly marked; a principle of very great importance."

Further directions are as follows: "Children should be urged to take part in the order and cleanliness of the desks, their own and those of the classroom at large. In the upper grades this interest should be extended to the school and community."

"The light should fall upon the desk from the left side. Eyes should never be closer than ten inches to the work." Observation in the schoolroom will probably show quite a number of noses within four or five inches of the pen-point.

"The eyes should be occasionally raised from the work. Books should be held off of the desks and in the hands, not laid down upon the desks." If the book is laid down the eye is placed at a disadvantage, shortening the vision, and the head goes down and then the hand comes up, the body is twisted and the whole child slumps down in a very characteristic and common fashion.

Physical Training.—Just here something should be said about physical training. This includes games in classroom, playground and gymnasium, and gymnastics of a formal type (*i. e.*, exercise at the command of the teacher); athletics, folk dancing, and the like. All of these serve different purposes and have correspondingly different results, which are important.

Educational Exercises.—The results desired from physical training are various; first, neuromuscular education, which is a mental thing. The muscles have nothing to do with it except to abide by the decision of the nervous system, which is trained by exercise. Who has not seen a city man in the country, particularly going down to a float on the river and confronted with the necessity of stepping into a boat. He will approach the edge of the float with great care, get down and grasp something, put one foot in and then perhaps he will fall overboard. He is a motor dullard, and the motor dullard is an increasing character of our population. On the other hand, another, no doubt, would walk confidently across the float, step in the boat, grasp the oars and row away. That is motor ability and the motor dullard can only hope to acquire it by exercise and training of the nervous system which controls the motor system. All of the seven hundred thousand youngsters in New York City and all school children elsewhere should have that kind of ability. It consists in coördination of the various body parts, ability to move with precision, ability to move at the right time, to be alert, accurate, definite, complete and graceful in movement. Most of these coördinations are unconscious, the result of practise, not thought about, but just done. Motor education is thus one of the greatest things in physical training.

Hygienic Exercises.—The other great thing resulting from physical training is health of body tissue by means of exercise of the muscles. When the muscles are exercised everything else in the body is exercised, the heart, the lungs, the arteries, the veins and the nerves, in fact the whole body is made to work in exactly the way it was intended that it should work. If each muscle were taken separately and exercised and brought to a condition of health, and also each organ, as the stomach, liver and spleen, and so on throughout all the organs of the body, it would prove quite a task. That is the modern method of education, by the way, but not modern physical education. Natural exercises of the muscles are used and nature stimulates the rest of the body in the process of repairing the busy muscles.

The method of evolution has been such that those whose muscles have been exercised in walking, jumping, climbing and throwing have survived, and those anemic beings that do not exercise do not survive. So our ancestors, in their more active physical life exercised and kept in health. Exercise is the only way. Therefore physical training is put in the schools to make the tissues of the children healthy and strong.

That is the hygienic side of physical training, a very different thing from the educational exercises previously described.

Posture.—Next, exercises are used to straighten the boys and girls. The debutante's dance of civilization has resulted in the toleration of such things as the debutante slouch, a very curious thing indeed; but if the children themselves are observed it will be seen that many of them have a slouch of the same kind. The chest is down and all of the contents of the thorax are pressed down upon the abdomen, which bulges; the head is hung down and the whole attitude is a picture of dejection. That is the result of acute or chronic fatigue, occasioned by bad health, lack of exercise, bad teeth and such hygienic errors. In short, poor posture is a depression due to lack of tone. Good posture on the other hand, is an attitude of vigor, characterized by a raised position of the various parts. If one stands tall, with head and chest held high, the whole body and the mind also are placed at the greatest advantage.

The children are being taught to stand up straight, because it is a sign of vigor, and in itself leads to a better state of health, both physical and mental, a fact easily proven to oneself. If one is mentally depressed, one is also, as a rule, physically depressed, and if he will stand up straight and lift his chest and forcibly get away from the physical depression, a mental uplift will be experienced. Actually more physical and mental vigor will be developed by using this very simple and cheap device.

Instruction in Hygiene.—The purpose of instruction in hygiene is to inculcate habits of cleanliness, care of the body, good posture, etc., which will maintain and promote good health and this superhealth, vigor. The emphasis of instruction should be placed upon the practical affairs of daily life. The modern method of education is one that takes the subjects and experiences of life and uses them as texts, considers them in relation to something new, and returns to the child a habit, a thought, a tendency to react in the proper way toward daily life.

Formerly a different method was used. It was the practice to present for inspection a bone that the child had never seen and probably never would see again, and consider that bone and other bones and finally the entire skeleton. Then the muscles and the nervous system were considered in turn. The structures of the body mastered, physiology was studied in the same systematic, logical manner. Then the children were told, in effect, "inasmuch as you are thus made and inasmuch as you see how all of these things which comprise your body work for your good or ill, you will readily see that you must do thus and so in order to keep well."

The structure of the teeth was taught, and how the teeth worked, and finally the care of the teeth. Now, in teaching hygiene, it is proposed to start with the tooth-brush and the use of the tooth-brush daily, four times a day and two minutes each time and endeavor to get a practical result immediately—the habit of using that tooth-brush.

It matters little whether the six-year-old child knows anything at all about the structure of the teeth or not, but it does matter much whether or not he learns to take care of them. Later he may be interested in the logical way in understanding what he has been doing, but children in the first grade in the elementary school are not logical persons despite the fact that many college professors are attempting to raise their children upon the basis of the theory that they are.

Hygiene is to be taught upon the basis of telling the children to do things, without emphasis upon the reasons for doing them, then seeing that they do them, which is most important of all, and last comes the logical motivation. The strongest and most effective motivation is compulsion. This may be reactionary, but it is effective. There are two methods. The first is a hygienic inspection of each child every day by the teacher, the object of which is to get the child into the habit of coming to school clean and orderly in person and in clothing. Second, to render concrete and practical the instruction in hygiene, to determine the ability of the pupil to put into practice the instruction received. They are told to do something. The next morning it is noted whether or not they have done it. Every morning the teacher will receive the pupils at the desk and look over two or three points among the following which are considered of importance: cleanliness of face, neck, eyes, nose, teeth, finger-nails and hair; collars, waists, caps, shirts, coats, shoes, outer clothing, handkerchiefs; books, lunch boxes, and desks. This daily inspection should include as many details as practicable. When unhygienic conditions are discovered an endeavor to cure them should be made by conference with the individual pupil in such a manner as not to occasion embarrassment. The children exhibiting certain symptoms indicative of disease are immediately sent to the physician. When this daily inspection of the children can be held, it will no longer be a common thing as it once was, for a pupil to come to school with red, inflamed eyes, with parasites in the head, with dirty clothes, grimy hands, black finger-nails—meanwhile getting a mark of "perfect" in hygiene for handing to the teacher a very carefully prepared picture of the skeleton of a human being.

There is a motivation for this sort of interest in personal hygiene and that is the desire of the child for approbation, or a reward of some kind. It may be developed individually or upon a class basis. In certain schools in New York placards have been used, which have a separate column for the records of each day of the week or month as the case may be. One placard is for clean teeth, another for clean faces, hands, etc., and so on through a selected list. The teacher tells the children that on the next day she will conduct an inspection of hands, and will put the percentage record of the class on this placard so that everyone who comes in may see what the standing of the class is in the matter of clean hands. Perhaps twenty will be found to have clean hands on the first day and thirty on the second. Perhaps the third day will be such a good day for base-ball that there is but slight gain—only thirty-two; the teacher then impresses the point that clean hands are important, and succeeds in sending the record up to forty on the fourth day, which will leave but a few of those who are difficult to reach, who may not have running water in the house, or who may not believe in clean hands anyway, but with some effort fifty may be reached. The next day it may be that one is absent on account of, say, toothache—due of course to lack of care of the teeth. And the ensuing days as they come along each provides a record for that class, a record of attainment, a record in which all are interested, to which all have contributed, and of which all are immeasurably proud. It is an effective method. The more it is considered, the more it will be seen that it appeals to many different kinds of human motives. This method might be recommended for application to brushing the teeth.

The second important new method is the endeavor to establish a daily routine for the purpose of regulating the daily health schedule. The teacher is requested to adapt a form for use in her own class, changing it from time to time. It is recommended that each child shall copy the schedule for himself or herself and take it home for his or her use. It should be hung up in some convenient and conspicuous place. The advantage of taking this schedule home is, first, that the child possesses something he has made himself and which hence is very much better and more effective than anything the Board of Education could issue; second, that the parents and other members of the family see the schedule and read it at least once. Possibly one out of three parents will become interested and say, "Well, there now, you follow that or I will whip you," taking the cue and applying it rapidly.

The following is a daily schedule:

MY DAILY ROUTINE.

Rise as soon as awake.

Throw bedclothes over foot of the bed.

It was found necessary to change the "rising as soon as awake" to "have a certain time for rising and keep to it," or words to that effect, for the reason that the child ordinarily took this too seriously, pushing aside all family regulations and authority and getting up at any time at all, whether daylight or not, and insisting upon staying up. This was only corrected by a note from the mother to the principal saying, "Please straighten this out because I am powerless against the authority of the school." At times this authority is stronger than we know.

Throwing the bedclothes over the foot of the bed helps to air the bed, and also makes it a place less comfortable than it was before and is therefore conducive to getting up.

The next item is setting-up and deep-breathing exercises. Undoubtedly a large number of New York City children do this. It is an excellent thing for them, or for anyone to do, and may be highly recommended for daily practise, even for dental hygienists. Teachers of hygiene and physical training should be impressed that the old proverb "Shoemakers' children go without shoes" is one to which they should give earnest consideration, and that they should take exercise themselves while teaching it to others. Everyone who has severe professional duties should make a careful search for the proper exercise to be taken before breakfast in the morning and rigidly adhere to it.

The schedule continues:

Wash with hot water and soap, and use scrub-brush on face, neck, and chest.

Use cold douche on neck and chest.

Clean finger-nails.

Brush the teeth.

Inspect clothes as to cleanliness.

Prepare for breakfast.

Walk for a few minutes in fresh air, if possible.

Use clean napkins and utensils, eating slowly and chewing food well.

Attend to toilet, washing afterward.

Prepare for school. See that books are clean and in order.

Obey rules about entering school. Be punctual. (The principal put that in.)

Take care of clothing and give attention to order of desk in school. Prepare for inspection.

Be careful of sitting and standing posture in school.

Drink water at recess.

Return home to lunch promptly.

Play in fresh air after school.

Attend to study of lessons and finish work quickly.

At night take care of outer clothing in preparation for bed.

Attend to toilet, wash, put clothes and school books in order for tomorrow.

Open windows top and bottom.

In short, these are affairs of daily life. They are things of actual experience which should be regulated, improved, changed and made better for the welfare of the pupils. It is a very different thing from book learning.

Brief reference may be made to the great development of athletics in New York and other cities, that brings to the child all of the normal, strong, competitive play happiness that would belong to it were it a normal child living under natural conditions. An effort is being made to put back into the lives of the chidlren big racial experiences of running and jumping, climbing, throwing and all competitive games as base-ball and basket-ball. If these things were not actually and definitely put into the lives of the children in New York City there would be a generation growing up through a playless childhood to be a menace to the race.

For the girls especially there have been brought over from the old world the charming, rhythmic play dances and folk dances that have been danced before cottage doors of the different countries of Europe. These have been handed down from generation to generation of children as priceless possessions of the race. These play-forms have persisted because they have been good and strong and healthful for the children. They have been taken and lifted from their natural setting and brought over to catch, as it were, the children that had left them behind in the places from which they had been transported.

Now our big groups of children, tens of thousands, even hundreds of thousands that have come from eastern Russia are given a chance to dance the Komarinskaia that their parents once danced in Russia. Stories could be told of the exhibition of feeling on the part of parents that have come from Odessa or thereabouts, upon witnessing their own children dance the dances they themselves had danced so long ago and so far away. The children themselves are less concerned with the origin of the dance. They will dance an Irish jig as happily as a real Russian dance, and the Irish children joyously swing into the lilt of the Russian and Italian dances.

Reference may also be made to the playground movement. During 1913–1914 one hundred and ten big public school playgrounds have been opened in congested portions of the city, and in these the children are given a chance to play. They have big iron gates, and where it was once a common sight to see the dirty street crowded with a heterogenous mass of children outside of these gates (now that the playgrounds are finally opened), one hundred and twenty thousand of them are playing in safety the games that belong to childhood. So these are the things which make up the essentials, and which are typical of the campaign for racial health under the conditions imposed by the city and the growth and development of the race up to its present civilized state. The share of the dental hygienist in the work of racial hygiene is of far greater importance than it has been possible to indicate here.

CHAPTER XVI.

FRESH AIR AND CORRECT POSTURE IN THEIR RELATION TO HYGIENE.

By PROFESSOR IRVING FISHER.

A COMPREHENSIVE study of the various aids to health is a necessary part of the equipment of a dental hygienist if she is to practise her specialty with any degree of intelligence. Her life-work is to be devoted to the prevention of oral lesions. The assistance of healthy bodies in the patients that come under her care will do much toward making her work a success. Hence, if she has so trained herself as to be able to give these patients proper suggestions in the form of hygienic rules whereby they may bring their bodies up to the normal state of resistance and health, she will have increased her sphere of usefulness to a marked degree. From such a viewpoint the subject matter of this chapter becomes at once of much practical importance.

There has been formed recently in this country an organization known as the Life Extension Institute, the object of which is to promote an interest in personal hygiene. The Hygiene Reference Board of this Institute, of which the writer is a member, has formulated certain rules of hygiene which may be classified under four headings: (*a*) air hygiene, (*b*) food hygiene, (*c*) activity hygiene, and (*d*) rest hygiene.

Under air hygiene there are four rules:

1. Let the fresh air in.
2. Go out after it.
3. Sleep in it, if possible.
4. Breathe deeply.

1. **Let the Fresh Air In.**—Mankind now lives in houses which shut out the fresh air, to which primitive man was accustomed, and interfere with its circulation, a fact which undoubtedly has much to do with the value of the fresh-air cure. It is not simply a matter of the freshness of the air, but also its motion and coolness which are largely responsible for its healthfulness.

Ordinarily, house air is bad because it is not fresh, not in motion, and is often too hot and too moist. A gentle draft is an excellent thing. Of course if the skin is not adapted to it through exercise and is, as a result, practically half-dead, the blood has not been properly oxygenated, and one is in a condition to be infected with any germ that may happen to be present. Under such circumstances a draft may produce a cold, but even a big draft will not have such an effect if one has accustomed his skin to an outdooor life. Therefore the hermetically sealed room is a menace, not only because the air is not fresh, but because there is no circulation of air. It is a great help, even, to have an electric fan going in a room, especially where there is no real ventilation.

Outside air should be let in so that there will be more freshness, motion, coolness and dryness. Fresh damp air, however, is preferable to close dry air, the fear of dampness being one of the many old-fashioned health superstitions. It is better to sleep out of doors in foggy air, than to sleep indoors in ideally dry air. In fact, air may be too dry as well as too moist, and generally is so in our houses in winter, the humidity often being as low as 8 to 10 per cent. of saturation, whereas it should be about 40 per cent. for health. The humidity of fog is 100 per cent., and yet, if all other characteristics of fresh air are present, it is not unhealthful.

But how is the fresh air to be let in? The best way is to open the windows, the objection to this being that, in the winter time, generally, the air flows in over the window-sill down to the floor and makes the feet cold, while the lungs fail to get the benefit of it. Unless the air is introduced intelligently through the windows they might almost as well remain closed. It is quite a simple matter to introduce outside air into a room through an open window in such a manner that it will not flow down on the floor and chill the feet but will shoot up to the ceiling and then come down like a shower all over the room to fill the breathing zone where it is wanted. This may be done by means of a window board, a board about three or four inches high placed vertically across the inner side of the window-sill, that is, in front of the bottom of the window but as far away from the window as the sill will allow, which is usually from two to four inches. If the window is opened not more than the height of this board the air that flows in strikes this board and is deflected upward instead of going down to the floor as it would if the board were not there. The air will continue on its way upward far beyond the height of the board, for it clings to the window, by virtue of a law of air motion whereby it follows a surface. Air does not leave a surface until it has been in contact with that surface for a comparatively long time, so that it may be carried even up to the ceiling to which it will cling in turn, traveling toward the center of the room before it drops down. In this way air may be forced to distribute itself throughout a room instead of forming a cold layer on the floor to chill the feet, while the rest of the room is filled with air that is hot and bad for breathing.

A room should be thoroughly aired before being occupied, and while occupied there should be a continuous current flowing through it. If it is possible to arrange for a cross draft a much greater circulation is created than when the air comes in only at one window, finding its way out as best it may, through keyholes and tiny cracks here and there.

Man was originally an outdoor animal and it has been impossible for him to break away from his inheritance entirely. It is but half a century since Darwin propounded the theory that the human race, instead of being an independent creation, has descended from the same stock as did the anthropoid apes. That conclusion is now generally accepted.

These primates had no houses but lived in jungles; their descendants, our ancestors, lived in caves, and not in hermetically sealed houses. And even after well-built houses came into use with following generations, there was still plenty of ventilation until glass was devised, when it was discovered that light could be let in without letting in the air, one serious consequence of which has been that the human race has been made the victim of tuberculosis. That is the price that had to be paid for running counter to nature. It is one of a hundred examples where civilization has upset the equilibrium of nature. Mankind today does not live biologically or physiologically, because the conditions which civilization imposes are foreign to the nature of his body. He was adapted for life in the open just as the monkey was. Therefore he lives at his peril in air-tight caves and must, if he would be healthy, recognize the necessity of restoring the original conditions to the extent, at least, of letting the fresh air in.

2 and 3. **Go out after fresh air** and **sleep in it,** do not depend entirely upon ventilation, for it is possible to get ever so much better results by being real outdoor men and women. Evidence such as is portrayed in the lives of centenarians and in the high death-rate among those whose occupations keep them indoors, and the low death-rate among those who have outdoor occupations demonstrates how great a benefit is the living out of doors. There is something about the outdoor air that is very different from that indoors. Living in a well-ventilated room is not the same as actually being out in the air. It is sometimes thought that this is due to certain electrical conditions, ozone perhaps, or the difference in the motion of the air, or variation in the radiation of light. It has been suggested also that while in the open the body radiates heat in every direction, but that indoors this heat is thrown against the ceilings and walls and comes back to the body. These, of course, are but theories, not actually proven as yet. Professor C. E. A. Winslow, Professor of Public Health, Yale University, Dr. James, of New York, Flügge and Paull, of Germany, have been working on this problem and all have come to the conclusion that it is not a matter of the chemical content of the air as was formerly believed. The number of grains of carbon dioxid in each cubic foot of air was at one time held responsible for air conditions. Experiments have since shown, however, that air in which the dioxid content has been very high has not subjected the person in such environment to headache or to a sense of closeness. As an instance, an experiment was made in Germany wherein a person was placed in a box, fresh air being supplied to him through a tube from the outside, in spite of which he complained of headache and a sense of closeness. His breathing

was all right, the air that passed into the lungs was pure, yet the fact that the body was not surrounded by fresh air made something wrong. In all probability it was that the heat of the body could not disappear as rapidly as when it was bathed in normal air.

Following this came another experiment in which conditions were reversed, the person being placed outside of the box in the fresh air, with a tube through which to breathe the bad air from the box. It was found that no symptoms of headache appeared as long as the body was exposed to the free-flowing fresh air outside. This would tend to show that the air with which the body comes in contact is fully as important as the air from which the lungs are filled.

In the same country another experiment was made, this time upon a cat, which was put in a rubber foot-ball, with the result that the cat soon died. Again a cat was placed with its head only in the foot-ball and this cat did not die; it lived on indefinitely as long as its body was exposed to good air. Therefore, it would seem, that to obtain any benefit from being out of doors one must not simply sniff the fresh air through a crack in the window or even sleep with head alone out of the window, as was tried in the treatment for tuberculosis a few years ago. It seems necessary to be out altogether.

Since the contact of the air with the skin is so important, air is evidently needed not only for filling the lungs, but for covering the body. Why this is so is not exactly known. Maybe because heat can pass more quickly from the body, or that waste products are eliminated by the action of the air on the skin. At any rate it seems perfectly evident that the body should be in the air. Before going to bed at night and upon rising in the morning are convenient times for real air baths, and it is well to emphasize the fact that an air bath is quite as important as a water bath. It is also possible for one to get an air bath even when fully clothed if the clothes are of such texture as to allow the air to come in contact with the skin. For this reason porous clothes are much better than closely woven garments and linen, and good conducting material better than woolen and other bad conducting material. The old idea of swaddling clothes, woolen underclothes and tightly woven underclothes meant that the skin was virtually being smothered. The clothes should be ventilated, as well as the house, and they should be porous through and through. When wearing such clothes it will be noted that the air will be felt against the skin, while persons clad in ordinary garments do not recognize that there is any air stirring. The wearing of porous garments will make the skin healthy, and from being waxy white, it will show a glow of health. And why not acquire red healthful bodies, as well as red cheeks, from outdoor air?

4. **Breathe Deeply.**—The following illustration from life serves well to impress this rule. It refers to a certain professor of philosophy who broke down nervously and was told by his physicians that he would never be able to do literary work again. He tried all sorts of

hygiene as they were presented to him and, although always obtaining some benefit for the effort, he would break down again upon returning to work. Finally, having tried about everything else he decided to study the Hindoo method of deep breathing. It is said that the Hindoos use this faithfully and, being a philosopher and interested in metaphysics, religion and theology, he began to read books on these subjects, whose authors associate certain physical exercises with their religion and philosophy, and have always claimed that the breath is closely related to the mind. He decided that he would go to the Ural Mountains in the south of Russia, and spend three months in deep breathing. He practised slow, deep breathing for an hour at a time, sitting erect in a chair, or lying straight out on a bed and breathing as deeply, slowly and evenly as possible. The result was that he completely regained his wonderful vitality.

Kant, the great philosopher, worked out some ideas on deep breathing before the physiological explanation was known at all, little even being known of anatomy and physiology. He practised deep breathing while walking about the streets. His belief was that the air circulated through his brain, enabling him to think better. He did not realize the physiological fact that the body required it to go through his lungs and from there into the blood. He arrived at the truth without knowing the basis of it.

A very good way to make sure that one is breathing evenly is to stop one nostril with the finger and breathe through the other nostril. When this is done it is possible to hear the air drawn in and any unevenness of breathing can be detected. This should be done first with one nostril and then the other until a habit of even breathing is established. Instead of breathing eighteen times a minute as ordinarily, respiration should be reduced gradually, to three or even two times a minute. At no time, however, should it be uncomfortably low.

It has been demonstrated that rapid, deep breathing without muscular exercise may result in illness. Professor Henderson, of Yale University, has made a comprehensive study of blood-pressure and the oxygenation of the blood, and has found by experiment that if deep breathing be forced, it so upsets the vital equilibrium as to actually do injury instead of being of benefit. Nature prescribes that there shall be an appetite for fresh air before it is taken in, just as that there shall be an appetite for food before it is eaten and to gorge oneself with fresh air is harmful, as it is to gorge oneself with food. For this reason exercise in connection with fresh air is very beneficial, because it creates a hunger for air. Ordinarily exercise and fresh air should go hand-in-hand, but this slow, deep breathing is practised to better advantage without exercise. The benefits of slow, deep breathing are many. First, the air gets into the more remote parts of the lungs. Ordinarily the tidal air or the air going in and out of the lungs at each respiration is but 10 per cent. of the air content of the lungs; that is, for every 100 cubic centimeters of air only 10 cubic centimeters go in and out during ordinary breathing. In deep breathing the lungs are almost wholly emptied and refilled from top to bottom, and so contain purer air, while more parts of the lungs are used. As a result the apices of the lungs, where tuberculosis usually starts, resist disease, and do not become anemic but rather are exercised, oxygenized and have vital force brought to bear upon them so that they are kept healthy.

In the second place, deep breathing calms the mind; just why it is hard to say exactly, but it is so. The Hindoos found this out before the scientists studied it, and there seems to be no doubt that they have the right idea about it. There is certainly a strong relation between the mind and the breath. When one feels sad, the first inclination is to sigh, sighing being but a modified breathing. When one is frightened, the breath will usually stop for the fraction of a moment, after which comes a sudden expiration. When angry, the breath comes fast. The breathing will respond to the mental condition very quickly. Of course the mental condition will also affect the heart beat, as well as many other functions of the body, but there seems to be a very definite relation between the mind and the breathing. It is often found that a person who is nervous, overstrung or working too hard, or one suffering with neurasthenia, who is shy and timid, afraid to approach people or has that peculiar fear that goes with certain kinds of neurasthenia, will often breathe in an irregular manner. If there is mental trepidation, there is trepidation in the breath; if there is mental calm, there is calmness in the breath.

The muscles of breathing are peculiar muscles; they are "semivoluntary." They operate ordinarily without thought, and during sleep they work up and down just as the heart beats back and forth. Much of the time one is not conscious of their working there is no volition. However, if one wishes to he can take a long breath, fast or slow, as he likes, so these muscles are called semivoluntary. If left alone they work themselves, that is, the lower nerve centers work them, but they are also controllable by higher nerve centers connected with the mind. It is probably because of this double control, voluntary and involuntary, that the character of the breathing exerts such an influence on the mind. At any rate, if one breathes slowly and rhythmically, it will tend to calm an agitated mind, and will often work as a cure for nervous prostration if persisted in systematically for a long time.

In the third place, deep breathing is advantageous because it empties the portal circulation, and this introduces the second part of the subject of the text, *i. e.*, posture, which at first thought may seem to have very little to do with fresh air.

Deep breathing empties the portal circulation of stagnant blood, and at the same time it supplies oxygen to purify that blood as it goes through the lungs, and takes the carbon dioxid away. It enables the nutritive processes to go on in the liver and the intestines without their being poisoned by this stagnant pool of blood which so many people carry about with them all the time. Deep breathing pumps that stagnant pool dry, as it were, and also pumps out the stagnant blood in the liver, which is closely connected with the portal circulation, a system of bloodvessels connecting the liver with the intestinal tube. These vessels are so large, so capacious, that they are capable of holding all the blood of the body, but if this system of bloodvessels should collapse and absorb the blood of the body, a person would bleed to death without any blood coming out of the skin, the blood merely sagging down into the abdomen. That sometimes happens, often after a surgical operation and is what is called "shock," but if the simple physical mechanism that produces shock were better known and the methods of preventing it, many of these cases of death from shock could be avoided. Sometimes a person will faint because the nervous equilibrium is upset; this causes the bloodvessels to expand, the blood goes into the portal circulation, the supply of blood to the head is almost depleted, not leaving enough to keep the brain working and consciousness is lost.

A surgeon should take the blood-pressure of his patient before and after operation. The importance of so doing may be well illustrated by the following case. A certain surgeon took the blood-pressure of his patient after an operation, finding that the instrument registered practically zero—the blood-pressure of a dead person. Instead of deciding, as many might have done that the patient was dead, or at least past all help, this man realized that the trouble was that all the blood had gone into the portal circulation through the nervous shock of the operation and, by tying a bandage around the abdomen of the patient and putting a hot-water bag under the bandage with a tube attached, into which he blew air, caused pressure to be distributed evenly over the abdomen which squeezed the blood out of the portal circulation and congested liver. This drove the blood into the bloodvessels of the body where it belonged, raised the blood-pressure and in a short time consciousness returned. That man owed his life to the fact that the surgeon understood the mechanism of the portal circulation.

Few people realize how large a part the portal circulation plays in their daily life or how often they upset its equilibrium. It is provided with a system of nerves and muscles, just as is every other bloodvessel. These nerves and muscles are known as dilators and contractors of the vessels and under normal conditions are adjusted to meet the requirements of the body. So far as the contractors are concerned, nature depends upon a certain amount of help or reinforcement from the pressure of the muscles of the abdomen. She expects a person to keep erect, which is the natural posture, so that there will be a certain pressure within the abdomen from the muscles that are pulled taut by the position of the body. In other words, every person who sits and stands erect exerts a certain amount of pressure upon the portal vessels by the tension of the abdominal muscles. Upon assuming a slouching position this pressure is immediately relaxed and nature cannot accomplish her full work. While a perfectly well person might afford to "slouch" for years without apparent injury, yet it is plain that the strain upon the contractors forces them to do more work to compensate for the lessened work of the abdominal muscles. The strain is analogous to eye-strain and has similar effects. If the person, however, becomes undertoned, and overstrains his general nervous system, there is not enough nervous force generated to keep the portal vein closed, and it will finally collapse. The contractors cease functioning owing to fatigue, and a form of nervous prostration called splanchnic neurasthenia is produced, one of the chief symptoms of which is "the blues," and which can usually be traced to an excess of blood in the portal circulation, very probably due to habits of slouching in sitting and standing, for such habits may very reasonably be considered as predisposing causes of disease. This is because the stagnant portal blood stream becomes filled with poison and the blood therein is in no condition to properly nourish the body, so that the individual becomes an easy prey to tuberculosis or any infectious disease.

Miss Jessie H. Bancroft of the American Posture League has compiled a book emphasizing correct posture for school children and through its pages has made an effort to improve the conditions in schools, advocating special chairs and various other changes in equipment to overcome bad posture. Chairs are responsible for a great deal of nervous prostration because they are apt to be built to induce slouching positions, and are but another illustration showing how civilization has upset the equilibrium of nature. Chairs are made wrong, and the effect has been overlooked. This defect of the ordinary chair may be overcome by placing a cushion at the small of the back so that the abdominal muscles are made taut, and it will be found that long-continued work will not be so tiring if the back is properly supported.

One way to force the blood out of the abdomen is to lie face downward with a pillow under the abdomen, bringing the pressure thereon. Dr. Osler recommended a patient to lie on the back and roll a small cannon ball over the abdomen. Another way is to take deep breaths in the right posture, breathing with the diaphragm as much as possible. This brings rhythmical pressure against the portal circulation which is also of great additional value in oxygenating the poisoned blood by giving it more air as it comes to the lungs.

But to obtain permanent results it is necessary to do more than this. The abdominal muscles must be strengthened for they have lost their tone. This means that they must be exercised, which should be done gradually. Frequently lying on the back and raising the head a little is sufficient to strengthen the muscles to a degree that will permit the raising of the whole body. This exercise combined with raising the feet while lying on the back will bring the abdominal tissues again into proper tone. It is well to remember, however, that if the cure is to be lasting, the cause must be entirely overcome. In other words, keep erect.

So it is that posture connects itself very distinctly with fresh air. In fact, one may take up any line of hygiene and find that it extends in its importance in all directions. To keep well it is necessary not only to look after the portal circulation and proper ventilation of rooms, but also the diet. The teeth—the instruments with which to handle the diet—must be kept clean, and like all organs of the body, given sufficient exercise to keep them well.

Truly the body is a "harp of a thousand strings" all of which should be kept in harmony. This chapter deals with but a few of the many strings, but to put and keep these few in tone will help to set all of the rest in harmonious vibration.

CHAPTER XVII.

LENGTHENING THE LIFE OF THE RESISTIVE FORCES OF THE BODY.

By WILLIAM G. ANDERSON, M.D., Dr.P.H.

The resistive forces of the body may be defined as nature's defences against harmful agencies. They are the weapons with which she combats the microörganisms of disease. They are the factors that are preëminently concerned in maintaining a healthy body.

That which the vast majority of individuals seek most is happiness and contentment. It is well to remember, therefore, that there can be no complete happiness or contentment without health. The purpose of this chapter is to teach those things that will, if applied, bring health.

Long ago the man who was called "the master of those who know, the private secretary of nature," Aristotle, the Greek philosopher, said: "The highest object of man is the attainment of happiness, and the highest happiness of man is to be reached by perfect virtue. Neither perfect happiness nor perfect virtue can be had without perfect health. The end of life, and therefore the end of education, is the attainment at once of intellectual, moral and physical virtue."

The element of interest is so closely associated with contentment that the modern teacher of physical training is adopting methods that appeal strongly to his pupils; he is striving to make bodily development interesting.

Sixty years ago Herbert Spencer in his work on Education referred to the failure of formal gymnastics to accomplish what had been promised in its name. For this reason he preferred the plays and sports that appealed to the young person. Gymnastics were fundamentally defective, formal exercises of a will-less character that could never supply the place of the movements prompted by nature. There is greater benefit in the riotous glee with which young people carry on their frolics. Fictitious exercise, *i. e.*, gymnastics, fail to give the benefit that natural spontaneous activity produces. While no person can lengthen the life of the resistive forces of the body who does not exercise in a rational manner, yet it is very desirable that the element of interest be present. Even what is termed "formal gymnastics" become less irksome if associated with noticeable bodily improvement. Students will gladly perform the "will-less movements" referred to if there is an apparent gain in poise, balance, grace, strength or skill.

Young men and women forget that it is the body which determines their efficiency, that they are only worth what the body will permit them to do. The muscles are merely instruments which act in accordance with the dictates of the will or the reflexes, and the better these instruments, the greater the good that can be accomplished. This is especially true in the case of those who have been well educated intellectually.

"It is more or less clearly recognized that no skill, no learning, no intellectual greatness can carry its fullest influence without a certain element of physical capacity in the individual."

The reader may prove an apt pupil "but the terrible earnestness of the race of life is not best met by mere scholarship." Horace Mann said: "At college I was taught the motions of the heavenly bodies as if their keeping in their orbits depended upon my knowing them, while I was in profound ignorance of the laws of health of my own body. The rest of my life was, in consequence, one long battle with exhausted energies." There is abundance of evidence of this character, and it comes too often from those who could have accomplished more if they had recognized the fact that there is no act of life, even thinking, that is independent of the body; the body means the brain and the neuromuscular machinery as well as the muscles. A mistaken idea prevails that only the contractile tissues are benefited by exercise. The brain substance is developed by voluntary muscular activity as are also the nervous elements connected with it.

There are, roughly speaking, two brains—one for movements, the other for intellectual activities. These are closely correlated, are interdependent, and the development of one will materially assist when the other is to be trained.

The muscle brain is called the motor area, the Rolandic division and, like its sister brain, is made up of millions of cells. Just as soon as a definite circuit can be made among the cells, and energy is liberated, skilled movement is the result. The muscle has not a scintilla of skill in itself, it is merely a servant.

The greater the number of "circuits" completed, the greater the muscular education of the person and the more reliable is the physical basis of psychic activity. Exercise is valuable in this respect because through pleasurable means permanent and trustworthy circuits are built. The muscularly versatile man possesses good brain substance which may be easily trained mentally, but like gold hidden in the ground, it is valueless unless used. The majority of college athletes stand well as students, many of them receiving honors.

In this connection it is well to discuss what is called "the physical basis of psychic activity" or the development of the brain substance by a variety of voluntary muscular movements. Making the directive centers of the brain skilful in muscular evolutions stimulates and assists the faculties. The late Professor Angelo Mosso testifies to the beneficial reaction upon the mind of diversified muscular movements.

Prof. Mosso cited the manual activities of the great Italian masters as in point:

"During the first epoch of the Renaissance the greatest artists of Florence were all apprentices in the workshops of goldsmiths. Lucca Della Robbia, Lorenzo Ghiberti, Fillipo Brunelleschi, Francia, Ghirlandajo, Botticelli, Andrea Del Sarto—to mention only a few examples—performed during their apprenticeship the simplest labors in the workshop of a goldsmith. But the exercises with which they gained their manual dexterity surely influenced also the development of their genius. . . . A fact which cannot be doubted is the many-sidedness of genius which some of the Italians of the Renaissance possessed, which has never again appeared with like copiousness."

The games and dances of the Greeks also must have assisted in the development of their genius, as, on the other hând, their intellectual exercises affected advantageously the development of the muscles.

The reference to another topic that is closely correlated to the lengthening of the life of the resistive forces of the body may create as much surprise as the allusion to dancing as an exercise. This is *grace*. Professor Layfayette B. Mendel, a man of international reputation as a physiologist, once said: "Train college students to be graceful. It is one of the most important results of a sensible scheme of physical training. The graceful man husbands his physical resources, he accomplishes much work with minimum effort."

Of two men with similar personal characteristics who perform, one immediately appeals to the onlookers, the other does not; one receives hearty applause, the other fails, and we ask at once, why? One is graceful. He conserves his physical energy, he spends just enough to make the movements accord with some standard that exists in the human mind. The other, performing the same evolutions, wastes his energy; is, in short, awkward.

There is within each individual a harp of emotions upon which chord of harmony or dissonance are struck by graceful or awkward movements. Precisely what this harp is, is not known; only a long and careful study of rhythm and harmony will answer the question. It is certainly there, and men are made either happy or distressed by the feelings that motion arouses.

Again it is well to emphasize the fact that the development of the muscles and the neuromuscular machinery is not the sum total of physical education. There are many who cannot become graceful or who find they are unable to acquire the poise and balance so necessary to complete bodily living, but they can at least keep in better condition the protective forces of the human mechanism by taking exercises and by living a hygienic life.

It is such a satisfying bit of information to know that if one is not able to acquire the beautiful physiques of the male or female gods he can at least add to his contentment and health by rational physical activity plus right living.

Man's enemies are infinitesimal, they are the germs which generate poisons in the body, and the bulwark erected by nature against these attacking forces is made up of builders and fighters which are also microscopic, the red and white blood corpuscles. Health depends upon the vitality of the tiny elements which constitute the protection against poisons, and it is perfectly possible to either strengthen or weaken these blood cells by methods of living. These guardians are reinforced by careful living, by rest, by rational and pleasing forms of bodily activity, hence the need of attention to hygiene and sanitation, to the observance of the laws of health, to exercise.

The forms of gymnastics that stimulate the action of the heart and lungs and the movements that wash out the organs and tissues of the body with fresh arterial blood go far toward the development and growth of healthy tissue cells; consequently the necessity for a certain amount of daily muscle activity. It is a mistake to suppose that a person must take violent or prolonged exercise. A very few minutes at a time will suffice. It is a mistake to think that a gymnasium is needed. A goodly part of the right kind of physical training can be taken in the sleeping-room, at the place of business, or on the street.

The most important kind of gymnastics is assuming and maintaining a correct standing or sitting position. In this case the many muscular groups of the body are brought into action. But little time is required and the desirable habit is soon formed. No apparatus is needed except the edge of a door against which one should stand several times a day. The posture may not be exactly ideal but it stimulates, and in a short time this straight door edge may be dispensed with.

Another very important factor in the development of the physical basis of psychic activity is the care of the five roads over which sensations travel to the brain. These roads are known as the senses. Hearing, seeing, feeling, tasting, smelling are improved if the machinery is kept in good condition.

The life of the resistive forces of the body are prolonged if the exposed mucous membranes of the body are often well supplied with fresh arterial blood, and rational exercise does this. Movements of the neck send the fluid tissue not only to the muscles but also to all adjacent areas, hence there is a building up of minute bodily substances in the eyes, the mouth, the ears, the nose, and the little builders and fighters are on duty to repair, or combat poisonous germs if they are present.

This is the crux of the whole discussion, as it will be at once seen that trunk movements will do the same for the contents of the abdominal cavity, and active leg work which stimulates the action of the heart and lungs will in a like manner protect and strengthen the cardiac and pulmonary machinery.

As the subject is too large to be easily handled in a satisfactory manner in one chapter, the standing position and the development of the thorax, or chest as it is often called, will be selected for treatment, and from this the student may evolve ideas that may be applied to other portions of the body. A good standing position means an arched chest, shoulders well placed, abdomen brought in, head erect and the whole body properly poised or balanced over the feet and legs.

HOW TO STAND WELL.

The erect posture is the normal pose of man alone; no other animal has this prerogative. It is therefore essential that we cultivate the vertical axis of the spine, insist upon our pupils' standing well, and teach exercises that will produce this result. Any deviation from the normal position will bring abnormal consequences, slight variations from the healthy condition of man.

The right idea of the standing position, coupled with will power, are essential factors needed in producing an erect posture. The gymnasium with its apparatus is unnecessary. Anyone may, many times each day, assume and maintain an erect carriage. In a very few weeks the entire contour of the body will change, and the improvement is not only esthetic but hygienic.

Should the reader wish to examine a careful work on the correct standing position, let him read *The Kinesiology of the Trunk, Shoulder, and Hip Applied to Gymnastics*, by William Skarstrom, M.D., of Wellesley College.

A well-known orthopedic surgeon has popularized the "erect-posture idea" by stating that in a way the various organs of the body are supported on shelves when the body is rightly carried, but as soon as the body is bent or habitually inclined the organs slip from their supports, and bring additional work to other structures that are already burdened with their own duties.

Dr. Joel Goldthwait, of Boston, in his paper read before the American Physical Education Association in Philadelphia, April 9, 1909, said:

"It should next be remembered that the pelvis represents the structural base of the body, that all of the trunk muscles are attached to it, that practically all of the thigh muscles are also attached to it, and that if for any reason the structural base is weak, the muscles that are attached to it, since they cannot act normally, must become weak. This means that it is useless to expect the muscles to regain their proper tone if the base to which they are attached is weak.

"Not only this, but it is unfair to expect that the body will be held in proper poise or used with normal freedom if the pelvis is weak, since the muscles cannot have their proper tone and the correct position must be difficult, if not impossible, to maintain. Not only is the proper tone of the pelvic joints of importance in maintaining the poise of the body, but if for any reason the correct poise is impossible, it means that not only is the posture imperfect, but that the viscera will be less well supported and their function less perfectly carried on. If the body is erect, the abdominal viscera are held in place by the muscles and by certain anatomical supports which lose their effect when the body droops, and it is because of this that many of the displacements of the viscera take place.

"Not only is this true, but if for any reason the erect posture is impossible, the spinal muscles become still further weakened as the result of the strain which must be thrown upon them, and with this weakening of the muscles about the spine the circulation in the spinal cord must also be interfered with—a fact which explains many of the nervous phenomena seen in such cases."

FIG. 218.—A diagram illustrating the attachments of some of the most important muscles which keep the body in the erect posture. *I*, the muscles of the calf; *II*, those of the back of the thigh; *III*, those of the spine. These tend to keep the body from falling forward. *1*, the muscles of the front of the leg; *2*, those of the front of the thigh; *3*, those of the front of the abdomen; *4*, *5*, those of the front of the neck. These tend to keep the body from falling backward. The arrows indicate the direction of action of the muscles, the foot being fixed. (From Huxley's Physiology.)

On this point Huxley says, in his *Physiology:* "But man possesses certain special or distinctive anatomical characters. The most noticeable, as seen on an external inspection of his body, is his erect position. He is, indeed, the only living creature that can walk or stand erect, *i. e.*, with the axis of the spine vertical; with the hip and knee-joints capable of being fully extended, so that the leg is brought into line with the thigh; with the foot so planted on the ground that it rests on the heel behind and on the roots of the toes in front; with the upper limbs so arranged as to act, not as instruments of progression, but of prehension; and with the head so balanced on the top of the spine that the face and eyes look directly to the front. His bones, joints, and muscles are constructed and arranged so as to enable him to preserve the erect attitude without fatigue. In other vertebrata the axis of the spine is oblique or horizontal; the hip- and knee-joints are permanently bent at a more or less acute angle; the limbs corresponding to the human upper extremities are, in the form of legs, wings, or fins, instruments of progression; and the head is articulated with the spine at or near the hinder end of the skull." (See Fig. 218.)

FIG. 219.—Defect. Right shoulder lower than the left, caused by overdevelopment of the right side.

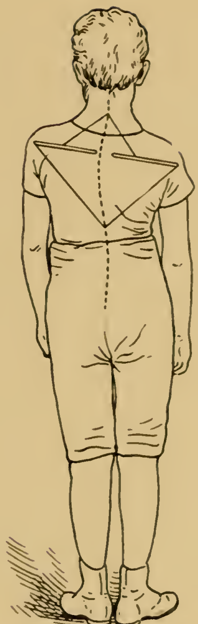

FIG. 220.—Shows uneven shoulders and a lateral curve in the spine caused by resting the weight of the body on one leg.

FIG. 221.—Projecting hips.

FIG. 222.—Side view of a well-built boy.

The foregoing may seem too technical, but it is written for those who are competent to teach others; it is not for the boy or the girl. A glance at the pictures will give a better idea of some of the variations in the standing position.

The following are simple rules for developing and maintaining the erect standing position.

Bring the heels and knees close together. If the conformation of the body prevents either, then bring them as close together as possible. Carry the hips well back and the chest forward. The shoulders should be level, the arms hanging naturally at the side but somewhat back.

The head should be erect, the chin slightly drawn in, and the eyes to the front or slightly raised.

FIG. 223. — Drooping head and flat chest.

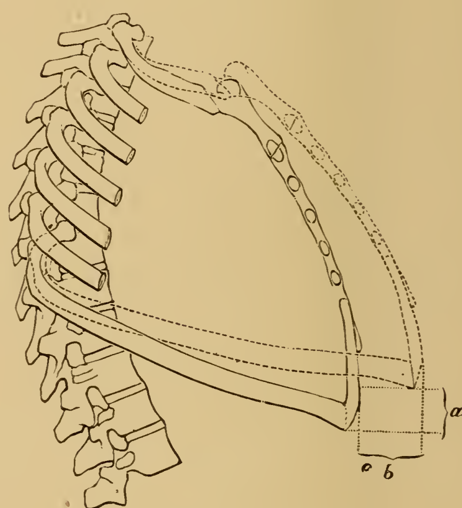

FIG. 224.—Diagram of the displacement of the ribs and sternum in inspiration. *a* indicates the degree of upward movement; *b*, that of forward movement. (Testut.)

The entire weight of the body should be well forward on the balls of the feet, not back on the heels. (See Fig. 222.)

Press the back of the neck against the collar.

Do not tilt the head backward.

If a large looking-glass is available, stand before this in the above position several times a day for only sixty seconds at a time.

Stand against the edge of the door three times a day for only one minute at a time, assuming the position above outlined.

Place in your looking-glass, or on your table, a card or some special object which will remind you to stand well. When the object is no longer effective, change it.

Train yourself to *think* of standing well.

THE DEVELOPMENT OF THE CHEST.

Too much attention cannot be given to the development of the "bony-cartilaginous cage that contains the heart and lungs." The widening and deepening of the "chest" is of vital importance, for here we find the never-ceasing pump and the machinery for the ventilation of the blood.

It was shown, when speaking of the standing position, that the *erector spinæ* group of muscles (back muscles) do much to maintain the erect posture. It is equally true that these same muscles are most active in arching the thorax, in raising the ribs.

Fig. 225.—Bent-arm position.

Fig. 226.—Stretch position, arms up.

This brief recital presents the principles that should govern us in the selection of exercises to correct flat chest, funnel- and pigeon-breast, and other forms of thoracic asymmetry.

1. Arch the thorax by the contraction of the back muscles.
2. Elevate the ribs by raising the arms above the head. (Fig. 226.)
3. Increase the capacity of the lungs by deep breathing and by active leg work, running, rope-skipping, etc.
4. Develop the heart by active leg work.

The above simple principles may be condensed into one general law, *i. e., to widen and deepen the thorax, raise the ribs.*

Movements of the ribs and the thorax as a whole. When breathing in, the thorax is enlarged in its three diameters—transverse, through, and vertical. The increase in the vertical diameter is caused partly by the elevation of the upper ribs, and the resulting widening of the spaces between the ribs, but is mainly due to the action of the diaphragm. The increase in the other two directions is due to the movements of the ribs, which are greatest where the ribs are longest, most oblique, and most curved at their angles (*i. e.*, at the sixth, seventh, and eighth ribs opposite the bulkiest part of the lungs), and least in the short, flat first and second ribs.

The above change in the thoracic diameters is brought about by the movements seen in Figs. 225 and 226.

CHAPTER XVIII.

THE TEACHING OF MOUTH HYGIENE TO SCHOOL CHILDREN.

By THADDEUS P. HYATT, D.D.S.

Almost anything is easy to follow if a few fundamental facts or truths are grasped, and work with children is no exception. Children are intuitive. Intuition in children controls and guides their emotions and feelings. These emotions and feelings are not formed into words or intellectual sentences, but are sensed through intuition. They know their relation toward others by their intuitive faculty and not by their intellectual development. Children are very simple. They rarely have affectation. They go direct to the subject and do not "beat about the bush" before coming to the point. Consequently the attitude taken by adults toward children must be absolutely free from pretence. It is of no use to pretend to love a child, for it will not be deceived. Love for children is a necessary requisite in handling children and this can be developed. Every human being is capable of developing love and affection. All that is beautiful in humanity is represented in the child. It is not yet contaminated by the materialism of the world.

Our attitude must always be that of being at oneness with the child. In addressing children it is necessary to talk with them, not to or at them. Include them with yourself. This inclusiveness must be real. The feeling must be one of inward reality. They will listen, and the feeling of inclusiveness will enable them to understand. Children grasp truths with the intuitive faculty or subjective nature which is in sympathy with the intuitive or subjective side of the adult. They will understand by their inner consciousness or subjective self-responding to, and receiving their impressions from, the subjective side of the adult.

Sometimes the child will be timid or afraid, and this is generally the result of his being unaccustomed to the strange new presence; and he must not be forced to make an outward expression when his inward consciousness is working on the newness of the personality which he has met. It is best to ignore him, for if attention be paid to him, his consciousness becomes confused and the child is injured.

As illustration, a mother brought two little sisters to the dentist's office. One became friendly at once, willingly ran into the operating room and jumped up into the chair. The dentist was able to work on her without difficulty. But the other child, keenly aware of the strangeness of the surroundings and the dentist, threw herself down on the floor, rolled and kicked and screamed. The dentist did not try to soothe her or to talk with her, but ignored her, going on with his work on the other child. Later the mother was asked to bring her with her sister the next time and leave her with the dentist but not to make any comments from one appointment to the next. The child, thinking the dentist intended putting her into the chair went into a temper and kicked and screamed again. Again she was ignored, the dentist leaving her entirely alone and going on with the work for the sister. Finally, as the strangeness wore off, she went over and stood by the chair, watching the work and looking at the dentist, which was what she wanted to do all the time, in order to become acquainted with the situation. She had thought she would be forced to get into the chair and when she found such was not the case, and that she was not even asked to, she began to adjust and understand her own feelings toward the dentist, and when at the third or fourth visit to the office he did ask her to get into the chair, she did it willingly and eagerly, after which all relations between her and the dentist were easy and happy. The morale of this illustration is that the undefined feeling for a new and strange personality must be respected and not suppressed. Another point of importance is the realizing of the child's equality with the teacher, and this is dependent upon two things. First, the absolute right of the child to have the truth, and nothing but the truth, told him in relation to the particular subject dealt with; and second, the child's right to be treated as a human being, as a member of the human family, and not as a little puppy or kitten. Children are human beings and they feel resentment at once if they are treated in any other relation whatsoever. They have ability to know and to understand through their intuitive side. It is folly to try to deceive them, for their intuition would tell them the truth in spite of deception.

Having established relations with children along these lines, the subject of how to address them must be considered. If methods based on the principles suggested are carried out, it will be found impossible to talk over the children's heads. The faults of the methods employed when it is said that someone "talked over the children's heads," or "the subject was too deep for the children" or "it was beyond their comprehension and understanding," lies with the person giving the address or talk, and not with the children. The child's mind goes direct. It travels in a straight line to the object. It is simple and needs very definite language to enable it to understand the subject under discussion. Adults who have perhaps gone beyond that stage of development are apt to use with children the language they might use with one another. Instead, language must be used that will go straight to the subject, with the fewest and simplest words. This knack can be acquired if it does not come naturally to the teacher, by study, by listening to those who have the ability of talking to children, and by writing. A good exercise in writing, where the words can be seen, is to discard and replace complex words with simple ones. When simplicity has been acquired the teacher will find scarcely anything the child is unable to understand. As an illustration: a little girl of four and a half years of age had become so absorbed in play she did not notice that the day had grown dark. Suddenly she went to the window and noticing the change she said, "The day is dark, the light has all gone out of it." What could be more simply expressed, yet so truthful, direct and clear? Anyone could understand it. It is even poetic in its simplicity. This is what is needed in talking with children—language that is simple yet clear and definite in expression.

During the activity of the intuitive and subjective nature of the child, it has no relation to or with the intellectual. Therefore those ideas or things which are to be appreciated or apprehended must be very definite in character and clear in formation. The child must have definite word pictures. No cubist or impressionist school can satisfy the child in the world of words.

It is important, too, to know the environment of a child. Not so much as to whether it has been brought up in luxury or poverty, as to whether it has been so placed as to need to use and exercise its own intelligence and direct its own activities, or whether it has been pampered and accustomed to have others do things for it. It is of course harder to work or talk with children that have been pampered than with those who have some self-reliance.

Children are best taught by means of stories. A good plan is for the teacher to write out in story form what is to be taught the child, rewriting and revising it until it is simple, direct and definite, always keeping in mind the definiteness of the idea and the simplicity of form. Stories may be told about animals' teeth, their size and shape and their several uses, and about the teeth of the children themselves, and why they are shaped differently in different parts of their mouth each to do its particular kind of work. Children are eager to learn. Nothing is so interesting to them as making discoveries. Therefore the bringing of a new idea to them in a way they can assimilate it, is interesting to them. If the subject is interesting, they will grasp it and absorb it. Kipling's "Just-So" stories are good examples for study, as they are definitely and simply told. If the form of these stories is adopted in telling stories to children, their interest will be held through to the end.

It is important that the children learn to express themselves, for they grow through expression. After some information has been given to them they should have time to absorb and digest it and to show that they have grasped and understood it, and then be asked to express themselves outwardly in some way. They should be encouraged in passing on the information to some of their friends. In their manner of teaching other children will be found valuable suggestions for the adult teacher. Children are efficient teachers and much can be learned from them.

The teacher must learn to act as interpreter, helping the children to understand things, material facts. An interpreter deals, not with theories, but with facts, directing attention and aiding understanding. The meaning of certain facts is interpreted to the child, he understands and acts accordingly, and thereafter is in the same relation to the facts as the interpreter or teacher. All of this will be appreciated by the child and creates a bond between him and the teacher and develops a sense of loyalty. He then has a responsibility and a duty to perform and will do what is being taught him, not just because he is told to, but because he has learned why. Thus children will not brush their teeth because they are told to, but will do so acting independently and because of their own knowledge and belief. They will realize the natural relation to the laws of nature which have been interpreted to them, and clean their mouths of their own volition, their own understanding.

It is hard always to take the positive attitude with children, yet it is the positive that educates. The negative form has no value. It is said that the commandment "Thou shalt not steal" has made more thieves than anything ever written, for the "shalt not" being negative entirely disappears, and "steal," which is positive, is the idea left. It is the positive which is impressed upon the mind. "Be good," is a positive statement and will have value. "Do not be bad," will have the opposite effect, tending toward badness as the idea left in the mind. Therefore, in dealing with children, every subject should be presented in the positive form.

While children are quick in their assimilation of intuitive knowledge they are exceedingly slow in the acquisition of physical facts. It will take them considerable time to know how to brush the teeth correctly, because they have not only to perform the act, not only to think of it, but have also to fix the impression. As in photography there is what is known as a fixing solution in which it takes time to fix the photograph, and which process cannot be hurried, so with the children—they need to have plenty of time to fix the impression and they should be given all the time they need. They are slow, necessarily, because there are no short routes in fixing impressions on the child's mind.

CHAPTER XIX.

INSTITUTIONAL DENTISTRY.

FOREWORD BY A. C. FONES, D.D.S.

ALTHOUGH there may be other reports concerning institutional work previous to that of Dr. J. F. Havestardt, of Boston, it is one of the earliest bearing on the elimination of the infectious diseases of childhood through mouth hygiene.

The report in full may be found in the *Dental Cosmos* for January, 1905. In the Poor Children's Home in West Roxbury, Massachusetts, there were about sixty children varying in age from two to fourteen years. None of these children ever had dental service and were obliged to live through the pain of exposed pulps and abscessed teeth. The institution was too poor to pay for such service, although it did employ a physician and buy drugs when necessary.

Dr. Hovestardt, moved to pity over the situation, attempted to cope with the awful mouth conditions he found there and gave one morning a week for several years until he secured clean mouths and sound teeth. In a part of his report he says, "In former years diphtheria and many other diseases have been prevalent at the Home, but for some time past not a single disease of the kind has been reported. In keeping the mouths of these children comparatively clean, and as free as possible from microörganisms, we greatly assist nature in her work, increasing the power of resistance to a large extent." The following is a letter to Dr. Hovestardt from the superintendent, Rev. F. Wilhelm:

"WEST ROXBURY, April 3, 1904.

DEAR DOCTOR:

If the enclosed record is of any use to you, I shall be pleased at any time to vouch for the correctness of the following statement or record:

Since the time you have taken care of the children's teeth in our institution, the health record has been remarkably improved. There has been no more typhoid or diphtheria. For this we have to thank, in the first place, God, but it is also due to the scientific and conscientious work you have done for the children. The doctor's and drug-store expenses for the past nine years have been as follows:

1895	$89.97
1896	70.94
1897	49.78
1898	45.61
1899	303.39
1900	38.29
1901	2.88
1902	3.80
1903	8.86

The reason that the expenses were so much higher in 1899 than in the preceding years was due to the fact that two newly arrived children had brought the measles and whooping-cough into the institution, and eighteen children were affected by the same. The sum includes pay for nurse. The great decrease in physician's and drug expenses is most markedly shown by the last three years, as the same have been reduced from $89.97 in 1895 to $2.88 in 1901, $3.80 in 1902 and $8.86 in 1903. Rev. F. Wilhelm, Supt."

A similar demonstration but one more impressive, because it involves a larger number of children, was made by Dr. Frederick A. Keyes, D.M.D., of Boston, at the St. Vincent's Orphan Asylum in Boston. Although he has been opposed to all dental nurse legislation as presented in Massachusetts up to the present time, yet his work and writings show that he is keenly interested in mouth hygiene. Many have different points of view as to how this problem should best be solved. Time alone will show which is the better plan. A full detail of his work at St. Vincent's Orphan Asylum may be found in the *Boston Medical and Surgical Journal* for July 25, 1912, and January 15, 1914:

INSTITUTIONAL DENTISTRY VERSUS INFECTIOUS DISEASES OF CHILDHOOD.

By FREDERICK A. KEYES, D.M.D.

All the great medical discoveries of the past decade have existed for centuries in the minds of theorists and dreamers. The fundamental principles involved are centuries old. The scientific and practical application of these principles for the benefit of mankind belongs to this generation. The relation of mouth hygiene to the infectious diseases, especially of childhood, seemingly the most demonstrable of all pathological etiologies, has been the last to receive the recognition which its importance has warranted. Dentists have been clamoring for years for coöperation from the medical profession in the elimination of disease. They have taken for granted the importance of their field of endeavor, and have been theorizing and proving by logical deductions the many diseases that might possibly be traced to unsanitary mouths.

During this period of complacency and theorizing, however, other professions have been experimenting and presenting facts to prove their theories. This is a scientific age. To prove the importance of any set of theories or opinions the facts must be at hand. To prove, therefore, to his own satisfaction that the truth of these theories so enthusiastically stated and upheld by his predecessors and contemporaries in the dental profession was warranted, the writer obtained permission to do dental work at St. Vincent's Orphan Asylum, Boston. Work was begun Nov. 10, 1910. In reviewing dental literature of the last fifteen years, very little information was found, bearing upon the methods prevalent in institutional dentistry, due to the fact that institutional dentistry in this country is a rarity. Although there may be defects in the system at present in vogue at St. Vincent's, nevertheless the writer has presented to the medical and dental professions two articles bearing on this subject through the medium of the *Boston Medical and Surgical Journal.* The methods employed in doing this work are described in the above articles. The results obtained from having this work done and its relation to infectious diseases of childhood are presented below.

St. Vincent's Orphan Asylum is the oldest institution of its kind in Boston. The care given to these children by the Sisters of Charity is unsurpassed; therefore the conditions existing here may be assumed to be as nearly ideal as possible in any institution of its kind in the country. In fact a comparative study of the records of institutions for the last ten years has shown that the ratio of infectious diseases here is extremely low.

The mouth conditions existing among the children when work was begun, Nov. 10, 1910, would startle even the most optimistic stomatologist. Of the three hundred children there was not one who ever had dental care, and there was not one child who did not need dental treatment. This condition exists in all institutions in this country where systematic dental work is not done.

The following is a summary of the work accomplished in the last thirty-six months:

	Nov., 1910, to May, 1912.	May, 1912, to Nov., 1913.
Total number of different patients examined	349	303
Total number of cleanings	272	350
Total number of cement fillings	25	45
Total number of amalgam fillings	72	76
Total number of cement amalgam fillings	69	60
Total number of temporary fillings	130	180
Total number of oxphas cu. fillings	9	57
Total number of teeth extracted (temporary)	290	102
Total number of teeth extracted (permanent)	131	51
Total number of abscesses opened	42	21
Total number of gums cut for permanent teeth	19	9
Total number of plastic operations	3	0
Total number examined and treated	1421	1245
Total number of fillings (including temporary)	315	418
Total number of teeth extracted (including temporary)	421	153
Total time spent (hours)	210	190

A study of the above table will give an idea of the gigantic problem confronting dentists in the handling of conditions existing in the mouths of the public school children of this country.

On page 466 is printed a table containing the number of infectious diseases occurring at St. Vincent's Orphan Asylum in the last seven years.

In the year 1905 to 1906 the Home was in quarantine for over three months because of an epidemic of scarlet fever of seventy-five cases. From the following data it may be seen that in the last thirty-six months but seven cases of infectious diseases have occurred at the asylum. Of these, six were measles, one of which was contracted previous to, or immediately after, admittance to the Home. The disease spread to five permanent inmates of the Asylum. The mouths of all the patients were carefully examined and found to be in need of dental treatment. Whereas in former years from ten to fifty children were stricken with measles, this year only five of them contracted the disease. The one case of diphtheria also occurred in a new girl. Examination of the mouths of these seven children showed great need of dental work. What conclusion must be drawn from this elimination of infectious diseases at St. Vincent's Asylum immediately after the beginning of dental work, and the continuance of this immunity for a period of three years?

RECORD IN REGARD TO INFECTIOUS DISEASES.

	1907 to 1908.	1908 to 1909.	1909, Nov. 1910.	Nov., 1910, to Apr., 1911.	Apr., 1911, to May, 1912.	May, 1912, to May, 1913.	May, 1913, to Nov., 1913.
Diphtheria	6	2	1	0	0	0	1
Mumps	8	3	10	4	0	0	0
Scarlet fever	17	8	12	8	0	0	0
Pneumonia	3	5	4	6	0	0	0
Measles	24	50	40	25	0	0	6
Tonsillitis	19	16	8	3	0	0	0
Whooping-cough	7	2	2	0	0	0	0
Chicken-pox	15	17	10	6	0	0	0
Typhoid	0	0	0	0	0	0	0
Croup	4	0	0	0	0	0	0
Spinal meningitis	0	0	0	0	0	0	0
Scarlatina	..	..	..	..	0	0	0
Bright's (acute)	..	..	..	..	..	0	0
Hemorrhage	..	..	..	..	..	..	0
Tuberculosis of the eye	..	..	..	..	1		
Tuberculosis of lungs	..	..	..	..	1		
	103	103	87	52	2	0	7

The above statistics demonstrate clearly that there must be some relation between unsanitary mouths and the infectious diseases of childhood. Dentists need no longer merely claim to be prophylactic agents in the field of medicine. The field is large and it is hoped that the presentation of the above statistics may stimulate others to do this work. I am sure their deductions and results will further strengthen the importance of oral hygiene.

A third demonstration, and one of unusual importance, was conducted at Marion School, in 1910, by W. G. Ebersole, M.D., D.D.S., Chairman of the Oral Hygiene Committee of the National Dental Association. Miss Cordelia L. O'Neill, principal of the school, supervised this demonstration and following is a report of this work by Miss O'Neill:

MOUTH HYGIENE. WHAT IT HAS DONE. WHAT IT CAN DO.

By CORDELIA L. O'NEILL.

Recently a prominent physician in an address at the Royal Hospital of London said:

"Oral hygiene—the hygiene of the mouth—there is not a single thing in the whole range of hygiene more important to the public than that."

He does not stand alone in his contention. But unfortunately the static approval rather than the dynamic refutation of this idea has nullified the results obtainable. School, as we understand it, is the training camp for life. School hygiene intelligently practised will produce healthy and efficient life. Hence the wisdom of utilizing every phase of hygiene during this important period of school training.

The purpose of this chapter is to present a report of an experiment made to test the value of oral hygiene to mental ability and growth.

No doubt it has been observed that the educational world is more conservative in making innovations to fit the exigencies of the times than any other working force. Before the first city in the United States adopted school medical inspection, pioneer work had to be done by the few to demonstrate to the public its value. The same experience came to the second city and so on down the ranks. Cleveland was nó exception. Conclusive proof in one community seemed to carry no weight in the neighboring communities.

In 1905 the opportunity presented itself of doing some work in medical inspection in the school building. Since we had always greatly respected the thought of "A healthy mind in a healthy body," and also because we had the executive authority, we seized the opportunity and had the work established.

At the end of four years the physical, moral and mental improvement due to the eradication of disease and the prophylactic effort of cleanliness was most marked.

In June of that year, 1909, the Cleveland Dental Society secured the permission of the Board of Education to make an examination of the pupils in four buildings of the city—Doan School in one of the beautiful resident sections of the East End; Lawn School in a middle class, well-to-do section in the extreme West End; Murray Hill School in an Italian settlement; and Marion School in a down-town congested, cosmopolitan and Ghetto section.

The results of the examination in the four schools representing different types of children showed that 97 per cent. of the mouths were in faulty condition. Among the 846 children examined in Marion School, only three were found whose mouths were in perfect condition. Many had teeth covered with green stain; some had two or three abscesses. Disease and neglect were very evident. That revelation was somewhat startling considering what had been done for the children. While it did not shatter our faith in medical inspection, it proved rather conclusively that, though medical inspection is very good, yet to get the best results, mouth hygiene cannot be ignored.

We were therefore quite ready to coöperate in experimental work when our assistance was asked by the Chairman of the Oral Hygiene Committee of the National Dental Association.

The proposition made by the dentist was that if the pupils practised oral hygiene, and if their teeth were put and kept in a clean healthy condition, their mental ability would be increased at least 15 per cent.

We knew that medical inspection for the four preceding years had increased the efficiency of our pupils, but we had no way of knowing how much improvement had been made. We were not disposed to encourage the Oral Hygiene Committee to gather any laurels from our medical inspection work; but we were most willing to lend every effort to discover any means of furthering the interests and improving the opportunities of our pupils.

We believe the educator should coöperate with any and every profession that can give aid to his work. We, as educators, should be the vanguard in the army of reform and improvement, not only to the pupils in the class-room, but to humanity at large. It is not for us to use tallow-candle methods in this age of electric light; or stagecoach theories in the day of the aëroplane. True, mental processes are the same as in the time of Plato and Aristotle, but present-day environment and requirements demand the greatest conservation of human energy. If the large manufacturing plants feel the necessity of maintaining at great expense experimental and chemical laboratories, if our government supports experimental stations to obtain the maximum result from the soil and farm products, is it not reasonable to believe that education can be much benefited by laboratory experiment and investigation? Therefore a justification exists for a school *teacher* assuming the responsibilities of an experiment suggested and planned by the committee of the National *Dental* Association.

We had no interest in the success of dentistry; and we undertook the work while in a critical frame of mind somewhat skeptical of the claims made, but willing to bear the chagrin of lost time and energy if the experiment was a failure; or receive sharp criticism of results and motives if it were a success.

Therefore we agreed to begin the work that would prove to us whether oral or mouth hygiene practised faithfully would increase mental power.

Our first step was to have all the pupils in the building carefully examined again by a competent dentist. His assistant recorded on duplicate charts the condition of the mouth and teeth of each pupil. From the charts of the pupils in the 4th, 5th, 6th and 7th grades we selected the 40 charts showing the worst oral conditions. We selected from those particular grades because pupils below the 4th grade could not sufficiently understand the requirements of the mental tests, nor of themselves carry out the practical care of the mouth. The pupils of the 8th grade would be promoted into high school before we had finished our experiment and we would have too much difficulty in getting the children together for group meetings. Having selected only according to the condition of the mouth and teeth, we found that the group of forty represented a variety of types of children. It was typical of the school. Some were bright, well-meaning; some had strong leaning toward incorrigibility, and the others varied between those two extremes. Many were behind grade. Of those who completed the tests 8 were up to grade; 9 one year behind; 5 two years; 3 three years and 2 four years.

The services of a psychological expert were secured. He planned six sets of tests. They were tests in memory, spontaneous association and differentiation, perception and calculation.

A nurse was engaged to have supervision over the children, and instruct them in the necessary practices.

The Chairman of the Oral Hygiene Committee of the National Dental Association had made all plans and was present when each and every test was made.

The assistant principal of our building, a special German teacher, and one room teacher assisted at the test meetings. With this corps of workers our first meeting was held May, 1910.

The children were told the purposes of the experiment. They were asked to assist us in making it; and were informed what would be expected of them if they decided to coöperate:

1. There were expected to attend each and every meeting called.
2. They were to brush their teeth three times a day during the entire time of the experiment.
3. They were to masticate their food thoroughly and were not to interfere with its proper insalivation by combining solid food with liquids during mastication.
4. They were to keep the passages of the oral cavity clear by correct inhalation.

Each child was to be given free of charge a tooth-brush, tooth-powder, drinking glass and any dental work necessary to put his teeth in good condition. Because of the very bad state of the mouths this professional work in most cases took considerable time.

Since we were dealing with children it was necessary to make our appeal fit the comprehension of our subjects. Pupils from the fourth to the seventh grade could hardly be expected to appreciate the value of dental prophylaxis and undergo much extra inconvenience to prove its worth to the doubting public. For that reason a reward of a five-dollar gold piece was promised to each child at Christmas if he faithfully did his work. This reward was feared by some to be the main incentive. But inasmuch as the children were just as faithful and responsive for the remaining seven months after the gold pieces were awarded as they were before, we looked upon the award as somewhat similar to the helpful little tug guiding the ship out of the harbor into the open sea where it is able to direct its own course. The thought of a tangible reward started the children in their practice. When they began to feel the benefit of the work they needed no further incentive.

When the children understood what was required of them five of the number immediately withdrew. They were unwilling to undertake the work.

The remaining thirty-five took the first psychological tests. These were, as before stated, prepared by a psychological expert. Minute directions were given as to the time allotted to each test; the manner of conducting each, and the credits in marking. Each of the tests were given by the writer. The psychological expert was present at the first and directed the manner of procedure. Each succeeding test

Fig. 227

was conducted exactly as the first. The tests were all taken at the same time of day; in the same room; and each child occupying the same seat first assigned him. The Chairman of the Oral Hygiene Committee of the National Dental Association timed the exercises with a stop-watch, always, however, assisted by one other timekeeper. The nurse with the three teachers mentioned before assisted in the distribution and collection of manuscripts and papers. The conditions and atmosphere surrounding the children during each test were as nearly uniform as it was possible to make them. The nurse marked all the papers following minutely each direction laid down by the psychological expert, thus assuring uniformity of judgment in giving credits.

Two tests were given before the children began to take care of their teeth; two were given while the teeth were being treated, and two after all work was finished.

After the first psychological tests were given the children were shown by the dentist how to brush their teeth. The nurse followed up the work in their homes and it was some time before several of them had mastered the process.

They were then taught how to masticate their food properly. Puffed wheat and cream was given them; the process of mastication and insalivation explained by the nurse; they all chewed it until the wheat was reduced to the proper consistency; then, when permission was given, they swallowed it. This was done to give them a correct idea of the proper consistency of food before it should be swallowed.

All the demonstration work was given in the school building. All the dental work except extractions and some work in orthodontia was also done in a dental room fitted up in the building. The nurse then visited in the homes at irregular intervals to see that each individual member understood and was properly carrying out directions. Every effort was made to preserve a perfectly normal atmosphere in the class-room and in the home of each child. No special attention in any way was attracted to these children in the dental squad. The meetings were held after all other children had been dismissed; notice of meetings was given individually and not by public announcement. In fact, so quiet and commonplace had been our work that some teachers as late as December of that year did not know who, if any, of their pupils were in the dental class. The above-named precautions were taken to reduce to a minimum any effect that might be produced by undue attention being attracted to the children. Anyone who has dealt with children knows that phenomenal results may be obtained from certain types by singling them out and bestowing on them unusual attentions. We strove to avoid any such stimuli.

Experiments with human beings are manifestly more difficult to conduct than with any other forms of nature. So many influences enter in to disturb the findings; so difficult is it to control conditions. An effort was made to anticipate every possible interference with a clear, just and candid result. We could see nothing to be gained by forcing conclusions and we stood ready at every stage to censure any movement that would favor the point sought. As we mentioned before, we had absolutely no interest in or desire for proving the correctness of the theory advanced by the dentist. So much for the preparation and conduct of the work. Now for results.

During the time of the experiment it was found necessary to drop eight from the class. If the pupils failed to attend meetings, showed evidence of neglecting to brush their teeth, or in any way violated directions, they were dropped. Only uniformly correct work could be considered. Twenty-seven pupils fulfilled every requirement for fourteen months to the complete satisfaction of those conducting the experiment. Their continuity of effort was most commendable and surprising.

Demonstrations of the home practice of the children were made during September and October in the school building. Each child showed the way in which he had been brushing his teeth. Results of daily application were very evident. A dinner consisting of meat, vegetables, fruit, breadstuffs, etc., was served. The children ate under close observation and each child showed that he mastered what had been taught him; that he was forming correct habits of mastication and insalivation.

The psychological tests were given as we said, two before, two during, and two after the oral imperfections were corrected. When the comparisons were made and the records of the tests completed it was found that the class average showed a gain of 99.8 per cent. plus, and that no individual gain was less than twice the 15 per cent. originally claimed. That is, those children, the majority of them repeaters, taken collectively, had almost doubled their mental power. Nor was that all. There was a very marked improvement in the health, complexion,

Fig. 228

appearance and conduct of the children. It was a revelation to those who were dealing with them. The self-respect that was engendered in each pupil by the consciousness of a clean mouth was of great value even if the improvement could not be calculated in the form of percentage. Making every allowance for a natural normal growth, as we knew these children, we believe the great improvement mentally, physically and morally was due to the practice of Oral Hygiene.

We will now review the case histories.

Six children did last year in twenty-four weeks the same work regularly done in thirty-eight weeks, and were graduated for high school in February instead of in June.

One child was quarantined on account of scarlet fever in his home. He helped nurse the younger children, and every one of the six children in the family contracted the disease except himself. The attending physician attributed his immunity to his healthy physical condition.

One child was weak and nervous, and subject to frequent headaches. Not only has she grown robust, but her headaches have disappeared.

Fig. 229.—Sol Katzel.

Fig. 230.—Frank Silverstein.

Fig. 231.—Jake Bernstein.

Fig. 232.—Joe Todd.

Fig. 233.—Lillie Gottfried.

One child, in May, 1910, was in the sixth grade. In May, 1911, one year later, he was graduated from the eighth grade, having accomplished two entire grades in one year. He had failed through indifference the year before.

Fig. 234.—Helen Wright.

One boy, at our district athletic meet that year (1911), won first place in the lightweight dash and first place in standing broad jump, securing almost two-thirds of all the points won by the school. The

Fig. 235.—Sam Katzel.

preceding year, although competing, he did not win one point; he says that his success was due to oral hygiene.

Fig. 236.—Ben Dimenstein.

A certain young girl had, I believe, the hardest struggle in the class. Her teeth were very irregular, the worst case of malocclusion the writer has seen. During the winter her mother met with an accident and was taken to the hospital for an operation, leaving in the child's care

FIG. 237.—Beckie Goldstein, aged thirteen years. Grade 6th. Average increase in working efficiency, 27.02 per cent. Marion School Class.

a baby two weeks old. This baby was the sixteenth in the family, and she the oldest daughter. For two months she, with the help of a

FIG. 238.—Rose Leiberman.

younger sister and with the advice and help of some women in the neighborhood, cared for the baby, regulated the household, and came

FIG. 239.—Lillie Semlakowsky.

to school occasionally one or one-half day when she found some neighbor who would take the baby for a time. By so doing she kept in touch with the work at school, and was promoted with her class in June. But the most remarkable fact is that during that time, though she had

FIG. 240.—Lillie Cohen.

not one unbroken night's rest on account of her anxiety for the baby, she retained her vigor and strength through it all.

FIG. 241.—Anna Pankuch.

Three girls now have beautiful sets of teeth, and have made a most marked improvement in complexion. Their improvement may be said to be esthetic.

FIG. 242.—Rachel Somers.

One girl had severe kidney trouble, and was a fragile, delicate, nervous child. In every respect she has greatly improved and is sturdy and well today.

Another girl led her class in the last promotions.

Seven girls in the dental class have shown improvement in scholarship, behavior, health and appearance.

FIG. 243.—Gussie Hammerschlag.

FIG. 244.—Beatrice Kramer.

FIG. 245.—Bertha Semlakowsky.

FIG. 246.—Sarah Macklin.

A young Russian girl has not had the full quota of mental endowments. She has been in America about three years. She has had

Fig. 247.—Frieda Goldman.

many difficulties to overcome, but nevertheless made a gain of 444.82 per cent., besides improving greatly physically.

Fig. 248.—Selma Perlick.

A certain young girl has been the most timid child in the class. Her fear of the dentist was such that at first the teacher remained with her, and held her hands while the dentist worked. She responded less readily, though she made a gain of 101.83 per cent.

Fig. 249.—Helen Cohen.

Two of the boys in the dental class have been good, faithful, steady workers and have made gains, besides brightening up and showing physical growth.

The banner pupil was a boy. He had ideas peculiarly his own as to what a boy's duties and privileges were. These ideas were so much

FIG. 250.—Hannah Cohen.

FIG. 251.—Ida Goldman.

FIG. 252.—Abe Meyer.

FIG. 253.—Harry Freeman.

at variance with the conventional standards that difficulties arose, which were seemingly insurmountable at times. Since working with the class he has been manly, tractable, and does not apparently have the temptations that repeatedly assailed him and were almost the means of his downfall. The result obtained for him alone was worth all our effort.

We believe that those children have been greatly improved by what has been done for them through living up to the rules of mouth hygiene. The smallest part of the good that came to them, it seemed to us, was the mental improvement which was being tested. Important as that was and significant as it may be, the gains of which we took no cognizance, and could not estimate equally, benefited the children both for themselves and for the community in which they are soon to be a factor.

Before the close of the tests, the teacher had each of the twenty-seven children write her a letter telling what he or she thought of the work which was being done. Each and every letter, though varying in other respects, spoke of the benefits the work had brought to them. They expressed their gratitude and they have not changed their atti-

FIG. 254.—Morris Krouse.

tude to this day. That was not unimportant. They have, so far as the writer has been able to follow, kept up the personal care of their teeth. The self-respect of a clean mouth is valuable. If we are today a race of food-bolters it may be worth something to start the next generation with the knowledge of the necessity of proper insalivation and mastication and help them to form the habit of putting that knowledge into practice. The purely physical benefits make it worth while, even without consideration of the mental. Though to education, in the common acceptation, mental power is of highest concern.

We have met the following criticisms since finishing our work:

First, it was claimed, the number of pupils was too small to furnish a basis for conclusions. When the United States Government was making its industrial investigations conducted by the Department of Commerce and Labor, 10 per cent. of any particular class was considered a sufficient number on which to base conclusions. We had selected the number which the United States Government considered sufficient, and that certainly was large enough for the purpose.

Again we were criticized for not taking weight, height, respiration, etc., before and after the tests. Since the physical growth of children during the adolescent period is great (that was the age of most of those children) we decided to attempt no testing along those lines. We confined our efforts to the one phase—growth in mental power. It was maintained before we began that it would be 15 per cent. Individually it was twice that. Taken as a whole it was doubled. But it carried with it a physical and moral growth.

We were further criticized because a control class was not carried; that is, a class who were given the tests but none of the mouth hygiene work. We attempted only one thing. That was to find out if there would be a gain. We were not sure there would be. Now both can be carried to test how much gain is due to mouth hygiene alone.

Dr. William Hunter, Physician to the London Fever Hospital, in an article on oral sepsis and again in an address before the faculty of the McGill University, Montreal, calls attention to the serious results that follow neglect to guard against diseased conditions in the mouth. After ten years of special investigation he has concluded that oral sepsis produces diseases of the tonsils, pharynx, stomach, liver and kidneys. He cites several instances in which the correction of oral conditions has cured the above-named ailments. He has put himself on record as believing that if all danger of infection from oral sepsis could be eliminated from the system, we might easily ignore all other sources of sepsis in the body since, as he says, "It (oral sepsis) is more important as a potential disease factor than any other source of sepsis in the body."

In every published report of school medical inspection of cities of the United States, that we have been able to obtain, the diseases of the mouth and teeth are found to be more numerous than any others on record. Dr. Hunter claims that the only reason the results of disease from septic mouths is not more prevalent is because of the great resisting power possessed by the mucosa of the mouth and gums. Why force our systems to resisting poison when the source of the poison might be eliminated?

Dr. Charles Mayo, of Rochester, Minn., said, "It is evident that the next step in medical progress in the line of preventive medicine should be made by the dentists. The question is, "Will they do it?" The schools cannot afford to wait to see if they do it. Medical inspection points out to us that the most universal physical defect is oral disease. The leading physicians here and abroad warn us of the serious results of oral sepsis. A sore on the surface of the body discharges its poisons without additional harm to the system. But the decayed tooth and the diseased gum send their poisons directly into all parts of the human system that will distribute it throughout the entire body. More disastrous results are prevented because nature prepares the antitoxin in the system to counteract the poison.

In our experiment with the children we found that when we relieved

Nature of the responsibility of counteracting disease by cleaning the mouth, she turned her attention to clearing the complexion, invigorating the body, stimulating the mind, producing thereby a much better quality of boys and girls. That is the aim of the school—the purpose of education. If our twenty-seven children were improved as greatly in one year by practising mouth hygiene, the same thing can benefit others. Not a child in that class received medical attention of any kind during the entire time, except one little girl whose adenoids were removed four weeks before the last test—too late to affect the results.

In this day of crowded factories and keen competition our children will be better prepared to assume the duties of citizenship if they have formed the habits of intelligent personal cleanliness and health. To accomplish this, we would repeat what Dr. Osler has said, that in the whole range of hygiene there is nothing more important than oral hygiene.

CHAPTER XX.

DENTAL HYGIENISTS IN PUBLIC SCHOOLS; AN EDUCATIONAL AND PREVENTIVE FORM OF DENTAL CLINIC.

By ALFRED C. FONES, D.D.S.

Owing to the interest that has been aroused throughout the country and the number of inquiries that have been made regarding the detail of the establishment and running of the preventive dental clinic in the public schools of Bridgeport, it would seem desirable to present reasons for this type of clinic in preference to the reparative type that has been established in a number of cities, and to describe, in considerable detail, the operation of the Bridgeport clinic.

It hardly seems necessary to present additional argument why the dental profession must, in some practical manner, solve this universal problem of decayed teeth and unsanitary mouths.

Few realize the pernicious condition of the teeth of the great majority of children in the public schools throughout the country, and those who have a realization of it are at a loss to find a solution of the problem. For the past few years our dental literature has teemed with articles on the evil results of unhygienic mouth conditions, and of late, since scientific investigations have been made of the systemic infections from pyorrhea alveolaris and blind abscesses, the necessity of adopting some practical plan to prevent at least a portion of this great evil must be plain to all. It might even be called the greatest evil, for there is nothing in modern civilization that is the cause, either directly or indirectly, of so much sickness as decayed teeth and unclean mouths. Such mouths are ideal breeding-grounds for germ life, and children with such mouths are far more susceptible to infectious diseases than those whose teeth are sound and whose mouths are kept clean and free from food débris. The most conspicuous defect of the child is the unsanitary condition of its mouth.

Before explaining our method of handling this preventive clinic, let us consider the proposition as a whole in order to better judge whether we are attacking the problem from a logical view-point or not. In almost all of our cities the children throughout the public schools will average close to six cavities per child. By multiplying the number of children in the public schools of a city by six, a fairly close estimate may be made of the number of cavities that should be filled. In a city of twenty thousand school children it would take a corps of twenty-five dentists nearly two years to properly restore these mouths to a sound and healthful condition. Such an expensive charity is clearly out of the question for several reasons: (1) Our city officials do not, as yet, sufficiently appreciate the immense importance of the teeth to good health to be willing to appropriate an adequate sum of money for the work. (2) Unless it were followed by a definite system of prophylaxis in the schools, such work would be only palliative, and in but a few years an equal number of cavities would again have accumulated. (3) Until a greater interest in the care of their mouths is aroused among the children and their parents, the making of such operative work compulsory would cause much trouble. (4) It is a hopeless and endless task, for it does not stop the flood at the source, but merely repairs the damages after they occur. Let the facts be accepted then as found and let it be admitted that the task of filling all the decayed teeth for the children is an impossible one. But by confining all efforts at first to the children of the first grade where the permanent teeth are just erupting, giving these mouths thorough prophylactic treatments four or five times during the school year, and educating the children, by tooth-brush drills and class-room talks, as to how to keep their teeth free from food, the decay of permanent teeth can, to a great degree, be prevented and the children saved from the necessity of extensive dental operations.

This is the system by which the Bridgeport clinic is operated.

As the children advance to the second grades the corps of dental hygienists, trained for the work, take care of them in their second year of school life. Again in the third year and so on up to and including the fifth year. Additional women are added to the corps when needed so that the child will have his teeth kept clean and polished during the first five years of his school life. From the beginning of the system there is always an army of children with clean mouths in the first grade, advancing the next year to the second grade. Again this clean-mouthed army advances into the third grade and so on up to the fifth, pushing before it those who have innumerable decayed teeth. In five years' time practically all of the children in the first five grades will have clean mouths and reasonably sound permanent teeth, and if this education and training means all that it should, in eight years the children in all the grades will have healthy mouths, with the newcomers entering into a definitely formed system.

Such a clinic becomes a part of the school life and is not to be considered in any sense as a charity. All children in the schools, whether of rich or poor parents, undergo an examination of their mouths and a prophylactic treatment of the surfaces of their teeth, accepting it as much a part of school life as their lessons in arithmetic or geography. A preventive clinic of this type is based on a system which harmonizes with our American institutions that have for their motto, "We help those who help themselves." In this way the municipality accepts one-half of the responsibility in aiding and educating the children to care for their mouths and to prevent dental decay. The other half, the home care of the mouth and the eating of proper foods, must be assumed by the child and his parents.

This work in the schools is essentially woman's work, and is the great field for the dental hygienist, to whom it opens up paths of usefulness, activity and inspiration hitherto undreamed of, allying her with the workers of the world who are helping humanity in masses.

LAW.

Section 12, Connecticut Dental Law, pertaining to Dental Hygienists.

"Any registered or licensed dentist may employ women assistants who shall be known as dental hygienists. Such dental hygienists may remove lime deposits, accretions and stains from the exposed surfaces of the teeth and directly beneath the free margins of the gums, but shall not perform any other operation on the teeth or mouth or on any diseased tissues of the mouth. They may operate in the office of any registered or licensed dentist or in any public or private institution under the general supervision of a registered or licensed dentist. The dental commission may revoke the license of any registered or licensed dentist who shall permit any dental hygienist, operating under his supervision to perform any operation other than that permitted under the provisions of this section." (Public Acts of 1915, Chapter 316.)

(When schools are organized for the education of dental hygienists within reasonable distance of the women of Connecticut, an effort will be made to have an educational and examination clause added to this section.)

LIMIT OF SERVICE.

From the preceding section of the dental law it will be noted that the hygienist is not permitted to fill teeth or to do any operations in dentistry, aside from that clearly specified in the law. Her field of service is confined to the surfaces of the teeth and the education of individuals regarding the home care of their mouths and the general subjects of hygiene.

ORGANIZATION.

The Bridgeport Board of Health appointed a sub-committee, known as the dental committee, to conduct the work in the public schools. This committee comprised four dentists and one member of the Board of Health, who is a physician. It had complete charge of the installation of the dental clinic in the public schools, selected the supervisors and saw to the selection and education of the dental hygienists. All their recommendations of appointment, however, had to be passed on by the Board of Health; also all expenditures of money, in order to have the work legal and in harmony with the city charter. Monthly reports are submitted to the Board of Health by the chairman of the dental

FIG. 255.—Dental corps in the public schools of Bridgeport, Conn., session of 1915–16, comprised of one woman dentist, two supervisors, and fourteen dental hygienists.

FIG. 256

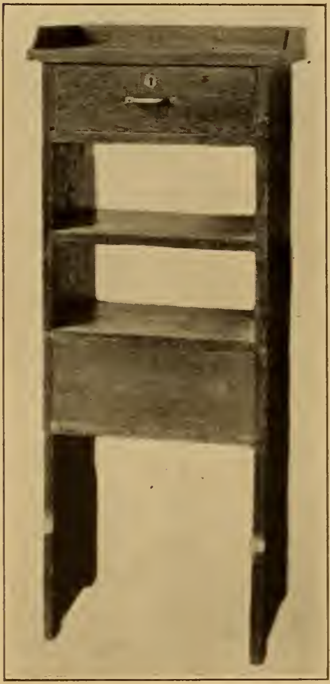

FIG. 257

FIGS. 256 and 257.—Cabinet. This form of cabinet has been found practical for use in the schools. Height, 36 inches; depth, $11\frac{1}{2}$ inches; width, 18 inches; upper drawers, $4\frac{1}{2}$ inches deep; lower drawer, $6\frac{1}{2}$ inches deep.

committee showing all work done during the month by the supervisors and hygienists.

Fig. 258

Fig. 259

Figs. 258 and 259.—Supply chest. One for each pair of hygienists, containing supplies necessary for three months. Inside dimensions: length, 24 inches; width, 20 inches; depth, 15 inches. Divided into two compartments—larger compartment 20 x 17 x 15 inches, smaller compartment 20 x $6\frac{1}{2}$ x 15 inches.

SUPERVISORS.

Two women supervisors were selected from a class of trained hygienists, one having been a visiting principal in the public schools, and the other a registered nurse. The duties of the supervisors are to supervise the work of the hygienists in the schools, each having an equal number of hygienists in her corps and under her charge. They give class-room talks, tooth-brush drills, attend to the distribution of literature to the children, and of all supplies to the hygienists, and make

Fig. 260—Supervisors and dental hygienists at work in school corridors.

arrangments for the location of the latter in the schools and for the moving of their equipments. The chairman of the dental committee keeps in touch with the supervisors, almost daily, by visiting the schools and he aids them in solving any problems that arise.

HYGIENISTS.

The hygienists usually work in pairs, two being assigned to a school, unless the school is exceptionally large. Each hygienist is provided with an equipment which becomes hers to work with and which she is

FIG. 261.—Supervisors and dental hygienists at work in school corridors.

supposed to keep in good condition. She is first taught how to assemble the portable chair and then to dissemble and pack it in its box. Each hygienist is required to own one complete set of instruments, polishers, water syringes, etc., the duplicate set being furnished by the Board of Health. This is done in order to insure good care of the instruments.

Hygienists' Equipment. The following list comprises the full equipment of each hygienist and includes the list and cost of supplies for forty weeks:

S. S. White foot engine		$25.00
Cabinet with drawers and shelves		8.00
Stool		10.00
S. S. White portable chair		50.00
Supply chest		6.00
Oil-cloth covers for chair, top of cabinet, and bibs (7 sets)		2.50
Two sets of instruments, long handles	Nos. 5, 6, 13, 14 Smith set oral prophylactic instruments, J. W. Ivory	5.20
	Nos. 17, 18 Darby-Perry excavators, S. S. White	1.40
	No. 3 S. S. White scaler, sickle-shaped	1.20
	+No. 5 S. S. White explorer	.50
Two sets of porte polishers	Large size, Small size — J. W. Ivory	6.00
2 Dun cheek-distenders—J. Austin Dun Specialty Co., Chicago		.50
2 mouth mirrors		2.00
2 tweezers		1.50
Phenol sodique (2 large bottles)		.90
Glass for phenol		.25
Pumice (10 pounds)		.50
Cotton pellets (3 boxes)		.75
Orange-wood sticks (2 doz. bundles large and 2 doz. bundles small)		4.80
Brush wheels		2.00
Glass for water		.10
Waste holder		.25
Cotton holder		.50
2 water syringes		1.00
Knife		.75
Scissors		.50
Floss (1 dome and 3 floss)		3.25
Rubber cups (2 doz.)		1.00
Platenoid mandrels for rubber cups (3)		.45
Carbolic acid		1.00
Iodine (24 oz.)		4.80
Ammonia		1.00
White vaseline		.50
Cheese-cloth for napkins (320 yards)		11.00
Denatured alcohol for sterilization (12 qts.)		2.40
Quart jar for alcohol		.10
Sterno-alcohol water heater		.50
Solid alcohol		5.00
3 brushes for instruments		.30
Ivory soap		1.00
Paper towels		5.00
3 brushes for hands and nails		.30
Oil for dental engine		.50
Cuttlefish strips		1.00
Shears		1.00
Permanent record cards.		
Examination blanks.		
Total		$172.20

LOCATION IN SCHOOLS.

The chairs are placed in the schools in an unoccupied room, if such is available, where the light is good and there is near access to running water. In many schools, where there is no such available room corridors are used, if wide enough to allow ample room for marching lines, or basement rooms, if light is good and there is sufficient heat.

Fig. 262

Fig. 263

Figs. 262 and 263.—Dental hygienists at work on unused stair landings.

Deep landings, or cloak rooms may also be used. A place may always be found in any school for the portable equipment.

HOURS OF EMPLOYMENT.

The dental corps arrives at the schools at 8.45 in the mornings, allowing fifteen minutes to prepare for the first child patients. They work until dismissal period of the first and second grades at 11.45,

Fig. 264

Fig. 265

Figs. 264 and 265.—Deep landings are sometimes utilized, when there is ample room for marching lines, or a cloak-room is often found to be convenient.

and beginning again at 1.30; they work through the school period in the afternoons and an hour afterward, or until 4.30 and also on Satur-

FIG. 266

FIG. 267

FIGS. 266 and 267.—There are times that the corner of a class-room has been used, or a basement, if there is sufficient light.

day mornings from 9 to 12. This period after school hours, from 3.30 to 4.30, and Saturday mornings is used for work for children other than those of the first grade.

EXAMINATION BLANKS AND RECORD CHARTS.

Figs. 268 and 269 show the form of record charts used.

Address Age

School	Room	Grade	Teacher

	Year	1914-15	1915-16	1916-17	1917-18	1918-19	1919-20
	Date						
State of Teeth	Clean						
	Fair						
	Dirty						
Color of Gums	Dark Red						
	Light Red						
	Pink						
Fistulae	Temp. Teeth						
	Perm. Teeth						
Malocclusion	Class 1						
	Class 2						
	Class 3						
Use of Tooth Brush	Daily						
	Occasionally						
	Not Used						
No. of Cavities	Temp. Teeth						
	Perm. Teeth						
Remarks							

Fig. 268.—Permanent record chart.

School		**Room**
Grade	**Teacher**	
Name		**Age**
Address		
State of Teeth	**Clean**	
	Fair	
	Dirty	
Color of Gums	**Dark Red**	
	Light Red	
	Pink	
Fistulæ	**Temporary Teeth**	
	Permanent Teeth	
Malocclusion	**Class 1**	
	Class 2	
	Class 3	
Use of Tooth-brush	**Daily**	
	Occasionally	
	Not Used	
Number of Cavities	**Temporary Teeth**	
	Permanent Teeth	
Remarks		

Fig. 269.—Form of daily examination slips.

The examination blank is of sufficient length to permit of the following being printed at the bottom of it:

To the Parents:

This chart shows the condition of the teeth and gums in the mouth of your child. We thought that you might be interested to see it. The inner circle in the picture shows the baby teeth and the outer circle shows the permanent teeth. Where you see a line drawn from a tooth it shows that there is a cavity in that tooth which should be filled by a dentist. We are trying to prevent your child's teeth from decaying by cleaning and polishing them every three months and teaching the child how to properly use a tooth-brush. You can aid us very much if you will encourage the faithful use of a tooth-brush and also bear in mind that candies, cakes, bread and crackers if left on the teeth will cause them to decay. Supervisor of Dental Clinic.

The marks on the teeth show the location of cavities on either the temporary or permanent set. From the examination charts, the findings are copied on the record charts which are kept throughout the first five years of the child's school life. After a copy is made from the examination chart, it is sent home by the child to the parents.

USE OF DENTAL ENGINE.

The use of the dental engine is permitted in polishing, when the child has never had his teeth cleaned before and the stains are difficult to remove. In such cases the hygienists are permitted to use Churchill's compound tincture of iodin, and the rubber cups with pumice in the dental engine, previous to going over the teeth with the hand polishers.

STERILIZATION.

Duplicate sets of all instruments used in or around the mouth during the prophylactic treatments are required in order to follow a proper system of sterilization. After a prophylactic treatment all instruments, polishers, cheek-distenders, water syringes, etc., are taken to the wash bowl and scrubbed vigorously with soap and a stiff nail-brush under a faucet of running water. The instruments are dried on clean cheesecloth and placed in a wide-mouthed quart jar filled with denatured alchohol and allowed to soak during the next operation which is carried on by means of a complete set of instruments which has just been sterilized in a similar manner. The girl's hands are scrubbed with soap and nail-brush under running water, after each prophylactic treatment. The backs and head rests of the portable chairs are covered with slips of white oil-cloth and are washed off with ammonia water after each child patient. The tops of the cabinets are also covered with oil-cloth, and over this is placed a fresh paper napkin preceding each operation, so that no infection may be carried from one child to the next from laying down instruments or polishers. Water for rinsing the teeth while operating is heated in small aluminum pans, on alcohol stoves, using solid alcohol or "canned heat" for fuel, to insure freedom from danger of fire or explosion.

The system of care, handling, and sterilization of instruments has been approved by an expert in bacteriology, and work, under what have been, at times, trying circumstances, has left no doubt as to the efficiency of such a system.

TOOTH-BRUSHES.

One of the problems is the securing of a good grade of tooth-brushes, children's and youths' sizes, that may be sold for five cents, and a larger or adult size for ten cents. Up to the present time factory seconds have been used, but the market will soon warrant a new brush for children, that can be sold at this price. Care must be taken in a school work of this character, to see that our public institutions do not become a field for the advertising of toilet articles, such as mouth washes or tooth-paste or powder. It would seem much better not to supply the children with samples of dentifrices, etc., but rather to give them a formula which they can have made up for a nominal price or to advise them how to detect abrasives that appear in some of the proprietary articles.

TOOTH-BRUSH DRILLS AND CLASS-ROOM TALKS.

On the day previous to the drill, a circular is sent home to the parents of the children telling what we wish to accomplish, and asking for their coöperation; they are requested to give their children five cents to pay for a new tooth-brush. At the time appointed for the drill the supervisor and her two assistants enter the school-room with the tooth-brushes, which have been sterilized, and a tray from the sterilizer, the supervisor standing in the front of the room and the assistants to the side or rear. The supervisor then inquires, "How many remembered to bring five cents for a nice new tooth-brush? Those who did, stand." The brushes are given to them, and they sit down. "Those who did not bring five cents and have no tooth-brush of their own, stand." Tooth-brushes are given to these with the understanding that they will be trusted to bring it later to their teacher for us. In many rooms the entire amount is collected; in some there are a few who fail to bring the nickel. But no penalty or reproach is meted out to them if they fail to do so, for the teacher knows that it is impossible for them to bring it, so the Board of Health must bear that expense. The brush question being settled the next step is the inspection of their hands to see if they are in a fit condition to handle the brushes. If not, they are sent out to wash them. Then comes a five-minute talk on the importance of the tooth-brush being used by its owner *only*, and on the reasons why no one else must use it, and why we need to clean our teeth; also on the times when we should clean our teeth, viz: "before breakfast, after breakfast, after dinner, before we go to bed." After this, according to a regular form, the drill proper is given, seated, with the assistants passing up and down the aisles helping the children to hold their brushes correctly, and to make the right movements. We have four positions for holding the brush and two movements in each drill. At the close of this part comes another five-minute talk on the care of the brush, emphasis being laid on the great necessity of keeping it clean, by a thorough washing in running water before and after using, on rinsing it constantly while brushing, and on having a clean place to hang it up when through brushing. The pupils are also asked to repeat a number of times when it should be used each day. Then the drill is repeated, the children standing up. It must be realized that these drills are intended to teach the children the correct form of brushing, and are not meant for the actual cleaning of the teeth, which cannot be properly done in the class-room without running water and dentrifrice. This would afford opportunity for making a muss, which makes it impractical for class-room work. Also, we believe it to be unnecessary.

Fig. 270

Fig. 271

FIG. 272

FIGS. 270, 271, and 272.—Supervisors and assistants giving tooth-brush drills in the schools.

At the close of this drill the children sit down, the brushes are taken up and placed in the slots of the copper tray, washed separately under running water and placed in the sterilizer to remain until the next day. The copper trays of the sterilizers are punched with holes large

FIG. 273.—A cheap, but practical and effective sterilizer.

enough to permit of suspending the brushes in, and representing the form of the class-room, seats and aisles, the head of each row of seats being numbered.

Formaldehyde gas is used as the sterilizing agent. The next day another drill is given, the brushes remaining in the sterilizer during the intervening night, after which the brushes are wrapped in waxed paper and given to the children to be carried home.

The teachers were asked to inquire as to who had brushed their teeth, the aim being to remind them of this duty and to assist them in forming the habit of daily brushing. We have been much pleased on return visits to find a goodly number of the children's mouths showing marked evidence of their having brushed their teeth regularly in the meantime.

On request for the brushes to be brought back for a drill, fully 95 per cent. have been brought back, and at least 95 per cent. of these were in fit condition to be used. The dirty ones are thrown away and new ones given in their places.

Fig. 274.—Brush wrapped in waxed paper, ready to be carried home.

TEACHERS' COÖPERATION.

Without imposing too much extra work upon the teachers, they may be asked to coöperate by having all children who have brushed their teeth stand and be counted, morning and afternoon, and the number marked on the blackboard. In turn those who have not brushed their teeth are counted and this number recorded also. Monitors keep these daily records in the various rooms and at the end of the month, the room having the best record is entitled to hold the honor banner, which reads: "Honor Class for Clean Mouths" for the succeeding month, or until the next record is taken. Those teachers who are especially interested in this work will often talk to their classes concerning the importance of sound teeth and clean mouths, and in this way aid in arousing the interest of the children and educating them upon the subject between the visits of the dental supervisors and hygienists.

PARENTS' COÖPERATION.

The parents' coöperation is secured principally by means of literature that is sent home to them by the children. The literature should be generously illustrated, as pictures attract the children and interest the parents more quickly. It is wise, in the beginning of this work, to first explain to the children in the higher grades what is intended to be done, as they can better understand it and will spread it more correctly throughout the neighborhood. As soon as the parents understand that the work is not a charity, that there is no filling and no pain attached to it, thorough coöperation from the homes is soon obtained.

THE SCHOOL DENTIST.

Upon entering the school in the first grade, when the children first come into the hands of the hygienists, it is frequently found that their six-year molars are slightly decayed, small cavities developing on the occlusal as well as on the buccal surfaces. It is extremely important that these small cavities be filled and the molar teeth saved, so a woman dentist is employed to go from school to school, with portable outfit and fill these small cavities in the six-year molars for the children in the first and second grades. This work we term preventive dentistry, as the effort made is to prevent development of large cavities in these important teeth. General reparative dentistry is not done in the schools in Bridgeport. In order to gain the consent of the parents for the filling of these teeth the card printed below in the form of a folder is sent home for the signature of one of the parents.

TO THE PARENTS OF...

Your child needs dental attention. This is the time to have the small cavities filled to prevent future loss of the teeth. If you have a regular dentist will you please take your child to have these cavities filled while most of them are small. If you have no regular dentist and wish them taken care of in school, free of charge, by the school dentist, please sign the attached card and return it to the teacher.

A. C. FONES, D.D.S.,
Chairman of Dental Committee.

ELIZABETH BEATTY, D.D.S.:

You are hereby authorized to do any dental work for my child that you may deem necessary, said work to be without any cost to me.

Signed.................................
Parent or Guardian.

There is no difficulty in securing plenty of volunteers and signed cards for this work. We believe that operative work of this nature can best be done in the schools where the children are so easily accessible. Much difficulty would be encountered if it were necessary to take them out of the schools to a central clinic.

In a well-organized school dental clinic provision must be made for the relief of pain, from toothache, for any children in the schools whose parents are too poor to pay for such dental service. Cards are printed and after being specially endorsed, by being countersigned with initials of the chairman of the dental committee, ten are sent to each of the principals of the various schools, who fill them in as needed, and give them to the children who are suffering. The child presents this card to a certain dentist in the center of town, and he relieves the pain. This may necessitate the extraction of a tooth or its treatment and filling. A record of the operation and the charge for it are made on the back of the card, and at the end of the month the cards with the bills are rendered to the chairman of the dental committee. These are checked up, and O. K.'d and the bill paid by the Board of Health. The relief clinic, operated in this manner, costs about $100 a year.

FIG. 275.—A woman dentist, with portable outfit at work in the schools.

STEREOPTICON LECTURES IN THE GRADES.

In order to educate the children in the higher grades also, it was found to be advisable to use stereopticon pictures, as they best hold the interest of the children and have proven to be the most instructive method of teaching this subject. The most practical lantern for this purpose is a Bausch and Lomb acetylin gas lantern. A curtain of white Holland linen eight feet deep, mounted on a roller eight feet long, makes the screen. This roller is supported, by a frame of black enameled gas pipes made in sections, with screw joints. Black alpaca curtains are used to tack over the windows of the school-rooms in order to obscure the light. About fifty-five slides make up the series for the first year's lectures. This includes talks on home hygiene and sanitation and its application to and effect on the body, the results of neglecting the mouth, appealing to the girls through their sense of beauty, and to the boys through their love of sports and ability to do things, and also to all the children through stories, emphasizing always that "A clean tooth never decays." As this educational work proceeds the children will be taught the proper way to use their teeth, how to masticate their food, and also what are the proper foods for their bodies. After the lecture, when the children are about to leave for home, literature is distributed to them which they are to take to their homes. This helps to impress the principal points upon the child and acquaints the parents as well with the subject we are anxious that they should know about and understand. Under this form of education, the younger children should show a much improved condition of the temporary teeth in a few years; while the lessons taught to the older children in school are taken home, and should result in the parents giving more attention to mouth hygiene among the little children yet too young to enter school.

During the years 1914–15, with a corps of eight hygienists and two supervisors, treatments and examinations were given to 6768 children. The total number of prophylactic treatments given was 14,340. The supervisors gave tooth-brush drills from October, 1914, to June 20, 1915, to 12,546 children.

The following table gives the details of our findings of the 6768 children on the first examination of their mouths:

State of teeth.			Color of gums.			Fistulas showing abscessed teeth.	Cases of malocclusion.
Clean.	Fair.	Dirty.	Dark red.	Light red.	Pink.		
401	2647	3720	1573	4731	464	691	6077

The use of the tooth-brush.			Cavities.	
Daily.	Occasionally.	Not used.	In temporary teeth.	In permanent teeth.
653	2149	3966	36,700	4555

The following table is of more interest, as it shows a comparison of the mouths of the 2780 children who have had three or more prophylactic treatments during the year.

Totals of first and last examinations of children receiving three or more prophylactic treatments during the year:

State of teeth.						Color of gums.					
First examination.			Last examination.			First examination.			Last examination.		
Clean.	Fair.	Dirty.	Clean.	Fair.	Dirty.	Dark red.	Light red.	Pink.	Dark red.	Light red.	Pink.
186	1067	1527	873	1769	143	647	1897	236	273	1981	526

Fistulas.		Malocclusion.
First examination.	Last examination.	
317	336	2494

USE OF TOOTH-BRUSH.

First examination.			Last examination.		
Daily.	Occasionally.	Not used.	Daily.	Occasionally.	Not used.
252	696	1832	763	1831	186

Cavities.				Increased number of cavities.	
First examination.		Last examination.		Temporary teeth.	Permanent teeth.
Temporary teeth.	Permanent teeth.	Temporary teeth.	Permanent teeth.	1623	499
15,547	1027	17,170	1526		

It will be noted that the increase of cavities in the teeth during the year has been considerably less than one cavity per child.

The dental corps of 1915–16 of fourteen hygienists are caring for nearly double the number of the previous year.

APPENDIX.

For the benefit of any dental organizations that might desire to educate a class of women as dental hygienists for private practice or for public service, as in schools, asylums, or hospitals, the following suggestions taken from a course in dental hygiene, both theoretical and practical, actually held, are submitted with the hope that they may prove helpful and of value.

THEORETICAL COURSE.

The theoretical course should extend over a sufficient period of time to give the class a good grounding in all essentials without crowding the lectures too close together. In the case in point the lectures were held in the evenings from 7.30 P.M. until 9.30 P.M., three evenings a week. This arrangement permitted women who were otherwise occupied during the day to take advantage of the course. The lectures were given according to the following schedule:

SCHEDULE.

Anatomy.
Physiology.
Anatomy.
Physiology.
Anatomy.
Physiology.
Anatomy.
Physiology.
Anatomy.
Physiology.
Bacteriology and Sterilization.
Special Anatomy.
Bacteriology and Sterilization.
Special Anatomy.
Bacteriology and Sterilization.
Special Anatomy.
Bacteriology and Sterilization.
Special Anatomy.

Inflammation.
Special Anatomy.
Skin Diseases and Syphilis.
Inflammation.
Skin Diseases and Syphilis.
Oral Secretions.
The Teeth as a Masticating Machine.
Dental Caries.
The Chemistry of Foods and Nutrition.
The Teeth as a Masticating Machine.
Dental Caries.
The Chemistry of Food and Nutrition.
Odontalgia.
Pyorrhea Alveolaris.
Malocclusion.
Alveolar Abscess.
Pyorrhea Alveolaris.
Malocclusion.
Alveolar Abscess.
Deposits and Accretions on the Teeth.
Dental Prophylaxis.
The Sanitary Aspect of Dental Operations.
Dental Prophylaxis.
Posture and Fresh Air.
Dental Prophylaxis.
Factors in Personal Hygiene.
Dental Prophylaxis.
The Teaching of Mouth Hygiene to School Children.
Dental Prophylaxis.
The Psychology of Handling Children in Office Practice.
Lengthening the Life of the Resistive Forces of the Body.

This order was deemed expedient to give best continuity in building up foundational knowledge. Each lecture on physiology followed the corresponding one on anatomy and covered the same ground. These two subjects might even be combined to advantage and given together by one lecturer.

The class assembled at seven-thirty and the first half-hour was devoted to a review of the previous lecture by one of the quiz masters, followed by the lecture of the evening.

In the equipment, student chairs with broad arms for writing were used for convenience in taking notes. A stereopticon with balopticon combination was also used, the balopticon permitting of the projection of illustrations from books, pictures or objects upon the screen.

Written examinations were held as soon as convenient at the completion of the most important subjects.

FIG. 276.—Graduates of first class of dental hygienists, June 6, 1914.

Fig. 277.—Afternoon class receiving practical instruction on manikins.

FIG. 278.—Evening class receiving practical instruction on manikins.

PRACTICAL COURSE.

At the conclusion of the theoretical course of various studies, the course of practical training in prophylaxis was arranged for and taken up.

The class of thirty-two women was divided into two classes, sixteen in each, one to work two hours in the afternoons, Mondays, Wednesdays and Fridays from 4 P.M. until 6 P.M., and the other on evenings of the same days from 7.30 P.M. until 9.30 P.M.

The lecture-room was cleared of its desk chairs and transformed into a veritable clinic-room.

The balopticon and the screen were left for use in the practical work, and sixteen modern dental chairs, with attachments of work tables and cuspidors, were installed, arranged around the room facing the center, four on each side and four on each end. Electric drop lights were hung over each chair.

Manikins, for first practise, were purchased and attached to the chairs in the place of head rests and hoods of rubber cloth made to fit under the chins and back of the jaws of the manikins to catch the water used in syringing the teeth. A piece of rubber dam about eight inches square, through which a hole was perforated for the rod attached to the manikin to pass through, was tacked to the wooden portion at the back of the head of the manikin. This arrangement inside of the rubber hoods deflected the water into the hoods. Eyelets on the upper corners of the bags and hooks on the manikins facilitated emptying the bags after use. In the center of the room a large sink was built, with running water, both hot and cold, and with zinc table large enough to accommodate a tub for boiling water to use for sterilizing instruments when the practical work upon children should be reached. The water was boiled and kept boiling by an electric heater. Sixteen deep metal cups, perforated near the bottom and fitted with wire handles which allowed the cups to be immersed in the boiling water and the instruments inside to be sterilized, were hung over and around the edge of the tub. Rolls of absorbent paper toweling for general use were attached to the sink, and bottles of liquid soap placed upon it. Upon the sink also were cans of powdered pumice and trays for alcohol to be used for sterilizing mirrors and handles of instruments that would not stand the boiling water.

Each pupil was provided, at cost, with a japanned box fitted with lock and key in which to keep her own instruments, and the following list of instruments andutensils also furnished her at cost:

LIST OF INSTRUMENTS AND UTENSILS.

Bib-holders and paper bibs.
Mouth mirror.
Phenol sodique (small bottle).
Holder for phenol sodique.
Darby-Perry instruments, Nos. 17 and 18. (S. S. White.)
Harlan instruments, Nos. 3 and 4. (S. S. White.)
Smith's set instruments, Nos, 5 and 6. (J. W. Ivory.)
Smith's set instruments, Nos. 13 and 14. (J. W. Ivory.)
Sickle-shaped instrument, No. 3. (S. S. White.)
Explorer.
Dunn cheek-distender.
Pumice dish.
Waste receiver.
Cotton pellets and holder.
Large porte polisher and large orangewood sticks.
Small porte polisher and small orangewood sticks.
Brush wheels.
Glass for water.
Water bulb.
Tooth-brush.

Each pupil was required to provide herself with two white linen aprons (Standard pattern, No. 6993), for wear at work and at practise, and the classes were ready to begin their lessons and training.

The first lesson to both classes consisted in a review of what had been given before in the theoretical course of the four motions, digital, wrist, rigid-arm and rotary, necessary to skill in handling both instruments and polishers, pictures being thrown upon the screen to illustrate them. The ordinary order of work—first instrumentation and then polishing—was reversed because the polishing would give the motions in more pronounced form, and so the class was instructed to place the large, orangewood sticks which had been previously cut and whittled to proper shape and size into the large porte polisher and the system of polishing begun.

The lights were put out and the picture illustrating the first division of polishing was thrown upon the screen. This was studied in regard to teeth involved, surfaces to be covered, grasp of the polisher, fulcrum-point for the hand and the motion used. After this detailed explanation the lights were turned on and each student applied these principles to the teeth of the manikin, the instructor passing from chair to chair to see that the work was being done correctly. This procedure was followed with each division, and the entire system of polishing greatly simplified for the pupils by the series of photographs of the different slides with which they were provided for their own use, as well as type-written lists of the seventeen divisions into which the mouth is divided for best convenience and least loss of time in changing positions.

The first five lessons were devoted to polishing according to the schedule appended, and then the first lesson in instrumentation was given. The class-room was open from 10 A.M. until 10 P.M. on the days when there were no lessons and on lesson days from 10 A.M. until 4 P.M., except that as the instrumentation lessons proceeded, time must be allowed for putting the mixture of plaster and varnish on the teeth of the manikins and letting it harden.

When the practical examination in polishing was held, the teeth of the manikins were removed and each member of the class required to blacken the set of another member with a broad carpenter's pencil, using an ordinary pencil for making fine lines around the margins of the teeth which were then reinserted and the examination begun. The class was given an hour and a half to polish off all pencil marks with large and small sticks in the porte polishers, using the moistened pumice on them, and were individually marked according to the number of pencil marks left on the teeth, three points being deducted from one hundred for each mark found. The theoretical examination on the system of polishing, as to divisions, surfaces, hold of instrument, fulcrum-points and motion was held over for the next lesson on account of lack of time. After this the lessons in instrumentation proceeded, as per schedule, and the room kept open as before for practise. The classes had access to the mixture of plaster and varnish to put on the teeth for practise, and afterward examinations on instrumentation were held. For this the instructor himself had the plaster and varnish put on the teeth, as nearly as possible to simulate the tartar which naturally accumulates in the human mouth, and allowed it to harden. The pupils were given an hour and a half for removing the deposits with the instruments and polishers, and were then examined upon their knowledge of divisions, teeth involved, surfaces; proper instrument to use—grasp of the instrument, fulcrum-point best adapted, and the correct motion.

After this examination, the classes were considered competent to work upon the mouths of children.

This work proved to be the most interesting part of the course for several reasons. It was the first practical application of theory and practice of the study of the year, and the enthusiasm of the classes in putting their studies into practical use and the apparent desire evinced by the children from all walks of life for having the work done and their mouths treated, was inspiration for all. Besides, it marked the realization of an ideal of the instructor and his assistant, the secretary of the course of training of dental hygienists, to reach and treat a large number of children with whom the results of the work may best be realized.

Application blanks were prepared and sent to the public schools, orphan asylums and organizations of boys' clubs, such as the Boy Scouts, and when applications were filed with the secretary, appointments were made for them with the operators (or pupils of the classes) filling up not only the lesson hours of Mondays, Wednesdays and Fridays, but for the practise days in between, Tuesdays, Thursdays, and even Saturday mornings—at all times when the children were not otherwise occupied in schools—so that when the lessons upon the children were begun, the operating time of both afternoon and evening classes for the entire two weeks to be devoted to the children was entirely filled. It was indeed inspiring when the classes met, to have all chairs filled, and a second relay of children waiting in the improvised waiting-room. Many without cards came on the chance that they might be taken care of.

Every child was requested by note printed on the appointment card, to bring his or her tooth-brush, so that all came prepared for the lesson in brushing that each operator was required to give her patient, the operators having previously been taught the scientific brushing of the teeth and gums by the instructor. This lesson served the double purpose of showing the children the proper use of the brush for future use and insuring a mouth free from food débris upon which to work.

The pupils were given operating blanks upon which they were required to note:

1. The Angle classification of occlusion.
2. The number of temporary teeth.
3. The color of the gums—dark red, light red, or pink.
4. Location of cavities in permanent teeth.
5. Fistulas.

The instructors passed from chair to chair, criticizing the work, correcting the charts, and instructing on special points.

As each pupil operated for two hours every day excepting Saturdays, and for at least one session on Saturdays, over five hundred children were operated on, which gave each pupil a great deal of practise, to say nothing of the benefit to the children.

Finally examinations were held, each pupil having but one patient for the last test in order to give her the full lesson time for the operation. For this 75 per cent. was allowed for perfection in operating and 25 per cent. for correct diagnosis noted upon the chart.

The next lesson began the last part of the practical course, the work on adult patients. The secretary sent out application blanks, as before, this time to the factories and shops and drew her applications for appointments from among the young women employed in them. There was not the enormous demand for this work that there had been among the children, although more than enough applications were received to fill all of the pupils' operating time. It was strongly emphasized, in sending out the application blanks and later, the appointment cards, that the work being done was purely educational and in no sense one of charity, the principal object in view being the teaching of the benefits of clean mouths, showing the patients the scientific use of brush, floss and wash—thoroughly treating their mouths, taking off tartar and deposits and thoroughly polishing their teeth, in the hope that mouth hygiene would not only be of lasting value to them, but might be spread in constantly growing circles.

The practise of the pupils was not lost sight of as the work progressed, the instructor examining and criticizing as before, until examinations were held and final marks given for skill in handling instruments and polishers and for thorough cleaning and polishing the teeth of the patients assigned.

This made the total length of time devoted to the practical course seven weeks.

SCHEDULE OF LESSONS ON MANIKINS.

POLISHING AND INSTRUMENTATION.

First.
Teaching the four motions—digital, wrist, rigid-arm, and rotary.
Grasp of polishers.
Direction of procedure for polishing.
First three divisions of polishing.

Second.
Fourth, fifth, sixth, seventh, and eighth divisions.

Third.
Ninth, tenth, and eleventh divisions, and review of entire labial and buccal surfaces of teeth of both jaws.

Fourth.
Twelfth, thirteenth, fourteenth, and fifteenth divisions.

Fifth.
Sixteenth and seventeenth divisions and review of entire lingual surfaces of teeth of both jaws.

Sixth.
Beginning instrumentation.
First two divisions.

Seventh.
Third, fourth, fifth, sixth, seventh, eighth, and ninth divisions.

Eighth.
Practical examination on polishing.

Ninth.
Theoretical (half-hour) examination on polishing.
Review of instrumentation—removal of varnish and plaster from teeth of lower jaw.
Divisions ten and eleven.

Tenth.
Twelfth, thirteenth, fourteenth, fifteenth, sixteenth, seventeenth, and eighteenth divisions of instrumentation.

Eleventh.
Review instrumentation, removal of varnish and plaster from teeth of upper jaw.
Divisions nineteen and twenty.
Use of floss for polishing approximal surfaces and use of brush wheel for occlusal surfaces.

Twelfth.
Examination. Instrumentation (practical) and instrumentation (theoretical).

SYSTEM FOR INSTRUMENTATION.

Division 1. Fig. 138.

Teeth.	Right lower molars, bicuspids, cuspid, lateral, and central.
Surface.	Lingual.
Instrument.	No. 18 Darby-Perry.
Grasp.	Pen-holder.
Fulcrum-point.	End of third finger between left lower cuspid and bicuspid on occlusal surface.
Motion.	Wrist or rotary.

Division 2. Figs. 139 and 140.

Teeth.	Left lower central, lateral, cuspid, bicuspids, and molars.
Surface.	Lingual.
Instrument.	No. 17 Darby-Perry.
Grasp.	Pen-holder.
Fulcrum-point.	End of second finger on cutting edge of right lower cuspid or lateral for left lower central, lateral, and cuspid. End of third finger on cutting edge of lower centrals for bicuspids and molars.
Motion.	Rotary.

Division 3. Fig. 141.

Teeth.	Left lower molars, bicuspids, and cuspid.
Surface.	Buccal.
Instrument.	No. 18 Darby-Perry.
Fulcrum-point.	End of third finger on labial surface of lower incisors.
Motion.	Wrist or rotary.

Division 4. Figs. 142 and 143.

Teeth.	Lower incisors, right lower cuspid, bicuspids, and molars.
Surface.	Labial and buccal.
Instrument.	No. 17 Darby-Perry.
Grasp.	Pen-holder.
Fulcrum-point.	End of second or third finger between left lower cuspid and bicuspid for lower incisors. Advanced on incisors for cuspid, bicuspids, and molars.
Motion.	Rotary.

Division 5. Figs. 144 and 145.

Teeth.	Right lower molars, bicuspids, and cuspid.
Surface.	Distal.
Instrument.	No. 13 Smith set.
Grasp.	Pen-holder.
Fulcrum-point.	End of third finger on cutting edge of lower incisors for distal surface of last molar. End of third finger on labial surface of right cuspid and incisors for the balance.
Motion.	Wrist and digital.

Division 6. Similar to Figs. 144 and 145.

Teeth.	Left lower cuspids, bicuspids, and molars.
Surface.	Distal.
Instrument	No. 13 Smith set.
Grasp.	Pen-holder.
Fulcrum-point.	End of third finger on labial surface of lower incisors.
Motion.	Wrist and digital.

Division 7. Similar to Fig. 146.

Teeth.	Right lower molars, bicuspids, and cuspid.
Surface.	Mesial.
Instrument.	No. 14 Smith set.
Grasp.	Pen-holder.
Fulcrum-point.	End of third finger on labial surface of right cuspid and incisors.
Motion.	Wrist and digital.

Division 8. Fig. 146.

Teeth.	Left lower cuspid, bicuspids, and molars.
Surface.	Mesial.
Instrument.	No. 14 Smith set.
Grasp.	Pen-holder.
Fulcrum-point.	End of third finger on labial surface of lower incisors.
Motion.	Wrist and digital.

Division 9. Fig. 147.

Teeth.	Lower incisors.
Surface.	Approximal.
Instrument.	Nos. 5 and 6 Smith set.
Grasp.	Pen-holder.
Fulcrum-point.	Third finger on chin.
Motion.	Wrist.

Division 10. Fig. 148.

Teeth.	Right upper molars, bicuspids, cuspid, lateral, and central.
Surface.	Lingual.
Instrument.	No. 17 Darby-Perry.
Grasp.	Pen-holder.
Fulcrum-point.	End of third finger on occlusal surface between left lower cuspid and bicuspid.
Motion.	Wrist.

Division 11. Figs. 149 and 150.

Teeth.	Left upper central, lateral, cuspid, bicuspids, and molars.
Surface.	Lingual.
Instrument.	No. 18 Darby-Perry.
Grasp.	Pen-holder.
Fulcrum-point.	End of second finger on cutting edge of right upper cuspid.
Motion.	Rotary.

Division 12. Fig. 151.

Teeth.	Left upper molars, bicuspids, cuspid, lateral, and central.
Surface.	Buccal and labial.
Instrument.	No. 17 Darby-Perry.
Grasp.	Pen-holder.
Fulcrum-point.	End of second finger on labial surface of left upper central and lateral and end of third finger on lingual surface of right upper central and lateral, for molars, bicuspids, and cuspid. End of third finger on cutting edge of right upper cuspid for lateral and central.
Motion.	Rotary.

Division 13. Fig. 152.

Teeth.	Right upper central, lateral, cuspid, bicuspids, and molars.
Surface.	Labial and Buccal.
Instrument.	No. 18 Darby-Perry.
Grasp.	Pen-holder.
Fulcrum-point.	Back of third and fourth finger on chin.
Motion.	Rigid-arm and rotary.

Division 14. Fig. 153.

Teeth.	Right upper molars, bicuspids, and cuspid.
Surface.	Distal.
Instrument.	No. 13 Smith set.
Grasp.	Pen-holder.
Fulcrum-point.	End of second or third finger on labial surface of lower incisors.
Motion.	Digital and wrist.

Division 15. Similar to Fig. 153.

Teeth.	Left upper cuspid, bicuspids, and molars.
Surface.	Distal.
Instrument.	No. 13 Smith set.
Grasp.	Pen-holder.
Fulcrum-point.	End of second or third finger on labial surface of lower incisors.
Motion.	Digital and wrist.

Division 16. Similar to Fig. 153.

Teeth.	Right upper molars, bicuspids, and cuspid.
Surface.	Mesial.
Instrument.	No. 14 Smith set.
Grasp.	Pen-holder.
Fulcrum-point.	End of second or third finger on labial surface of lower incisors.
Motion.	Digital and wrist.

Division 17. Similar to Fig. 153.

Teeth.	Left upper cuspid, bicuspids, and molars.
Surface.	Mesial.
Instrument.	No. 14 Smith set.
Grasp.	Pen-holder.
Fulcrum-point.	End of second or third finger on labial surface of lower incisors.
Motion.	Digital and wrist.

Division 18. Similar to Fig. 147.

Teeth.	Upper incisors.
Surface.	Approximal.
Instrument.	Nos. 5 and 6 Smith set.
Grasp.	Pen-holder.
Fulcrum-point.	Back of third or fourth finger on chin.
Motion.	Wrist and digital.

Division 19. Fig. 154.

Teeth.	Lower.
Surface.	Buccal, labial, and lingual.
Instrument.	Sickle-shaped.
Grasp.	Pen-holder.
Fulcrum-point.	End of second or third finger on cutting edge of incisors.
Motion.	Digital. Draw stroke.

Division 20. Fig. 155.

Teeth.	Upper.
Surface.	Buccal, labial, and lingual.
Instrument.	Sickle-shaped.
Grasp.	Pen-holder.
Fulcrum-point.	Back of third or fourth finger on chin; or fist grasp—end of thumb on occlusal surface.
Motion.	Digital. Draw stroke.

Division 21.

Instrument.	Nos. 3 and 4 Harlan.
Use	For small, hard, tenacious deposits under gingival border.
Motion.	Draw stroke.

SYSTEM FOR POLISHING—LARGE STICK.

Division 1. Fig. 158.

Teeth.	Upper right central and lateral.
Surface.	Labial.
Grasp.	Porte polisher held in fist.
Fulcrum-point.	End of thumb on cutting edge of right cuspid.
Motion.	Digital.

Division 2. Fig. 159.

Teeth.	Upper right cuspid, first and second bicuspids.
Surface.	Labial.
Grasp.	Fist.
Fulcrum-point.	Back of third finger on chin.
Motion.	Rigid-arm.

Division 3. Fig. 160.

Teeth.	Upper right molars.
Surface.	Buccal.
Grasp.	Pen-holder.
Fulcrum-point.	Back of third or fourth finger on chin.
Motion.	Rotary.

Division 4. Similar to Fig. 160.

Teeth.	Lower right molars.
Surface.	Buccal.
Grasp.	Pen-holder.
Fulcrum-point.	Back of third or fourth finger on chin.
Motion.	Rotary.

Division 5. Similar to Fig. 159.

Teeth.	Lower right bicuspids and cuspid.
Surface.	Buccal.
Grasp.	Fist.
Fulcrum-point.	Back of third finger on chin.
Motion.	Rigid-arm.

Division 6. Fig. 161.

Teeth.	Lower incisors.
Surface.	Labial.
Grasp.	Fist.
Fulcrum-point.	Thumb or first finger of left hand, depressing lips.
Motion.	Rigid-arm.

Division 7. Similar to Fig. 159.

Teeth.	Left lower cuspid and bicuspid.
Surface.	Labial.
Grasp.	Fist.
Fulcrum-point.	Back of third finger on chin.
Motion.	Rigid-arm.

Division 8. Similar to Fig. 162.

Teeth.	Lower left molars.
Surface.	Buccal.
Grasp.	Pen-holder.
Fulcrum-point.	Back of third or fourth finger on chin.
Motion.	Rigid-arm.

Division 9. Fig. 162.

Teeth.	Upper left molars.
Surface.	Buccal.
Grasp.	Pen-holder.
Fulcrum-point.	Back of third or fourth finger on chin.
Motion.	Rigid-arm.

Division 10. Similar to Fig. 159.

Teeth.	Left upper bicuspids and cuspid.
Surface.	Labial.
Grasp.	Fist.
Fulcrum-point.	Back of third or fourth finger on chin.
Motion.	Rigid-arm.

Division 11. Similar to Fig. 158.

Teeth.	Left upper lateral and central.
Surface.	Labial.
Grasp.	Fist.
Fulcrum-point.	End of thumb on cutting edge of right central.
Motion.	Digital.

Division 12. Fig. 163.

Teeth.	Right lower molars and bicuspids.
Surface.	Lingual.
Grasp.	Pen-holder.
Fulcrum-point.	Back of third or fourth finger on chin.
Motion.	Rotary (or using side of stick with rigid-arm motion).

Division 13. Fig. 164.

Teeth.	Right lower cuspids and incisors.
Surface.	Lingual.
Grasp.	Pen-holder.
Fulcrum-point.	End of second or third finger from cutting edge of incisors to first bicuspid.
Motion.	Rotary.

Division 14. Fig. 165.

Teeth.	Left lower cuspid, bicuspids, and molars.
Surface.	Lingual.
Grasp.	Pen-holder.
Fulcrum-point.	End of second finger on labial surface of lower incisors.
Motion.	Both rigid-arm and rotary.

Division 15. Fig. 166.

Teeth.	Left upper molars and bicuspids.
Surface.	Lingual.
Grasp.	Pen-holder.
Fulcrum-point.	End of third finger on labial surface of right lower lateral or cuspid.
Motion.	Rigid-arm (or third finger on masticating surface of right upper bicuspid, rotary motion).

Division 16. Fig. 167.

Teeth.	Left upper cuspid and upper incisors.
Surface.	Lingual.
Grasp.	Pen-holder.
Fulcrum-point.	End of second or third finger on cutting edge of right upper cuspid.
Motion.	Rotary.

Division 17. Fig. 168.

Teeth.	Right upper cuspid, bicuspids, and molars.
Surface.	Lingual.
Grasp.	Pen-holder.
Fulcrum-point.	Back of third or fourth finger on chin.
Motion.	Rotary.

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