DOCUMENTS

AND THEIR

SCIENTIFIC EXAMINATION

WITH ESPECIAL REFERENCE TO THE
CHEMISTRY INVOLVED IN CASES OF SUSPECTED FORGERY,
INVESTIGATION OF DISPUTED DOCUMENTS,
HANDWRITING, ETC.

BY

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PREFACE.

THE scientific examination of documents as a branch of forensic chemistry has been strangely neglected, and hitherto there has been no work dealing fully with the subject from all points of view.

The present book is based upon personal experience extending over many years, and includes the results of a great variety of investigations on such subjects as the composition and behaviour of inks, pencil pigments, sealing wax, and other writing materials in connection with their use upon documents. Some of these results have been communicated to scientific societies and subsequently published in their journals, and so have had the advantage of being discussed and criticised by experts in the respective subjects. The questions of the materials upon which the writing, typing or printing appears, of handwriting, of finger-prints, photography and microscopical examination are all inseparably connected with the scientific examination of documents; and these I have dealt with in due proportion to the whole subject, bearing in mind works already available.

For the purpose of presenting expert evidence in legal cases, criminal charges, the investigation of anonymous letters, and the like, such studies are of material importance, and, as little information on the chemical questions involved was available, I had to make prolonged laboratory experiments to obtain trustworthy results, and these records should prove of service to others.

In connection with the chemical examination of documents I am privileged to make use of numerous details of cases and observations recorded by Mr. A. Lucas, Director of the Government Laboratory, Cairo, whose excellent work on "Forensic Chemistry" contains short sections on the subject. My best thanks are also due to Mr. A. E. Osborn of New York for valuable information kindly sent to me, and for several illustrations, as well as for permission to quote from his standard work "Questioned Documents."

The Publication Committee of the Journal of the Society of Chemical Industry has kindly lent the blocks of photomicrographs of pencil markings illustrating a communication of mine to that Journal, for which I am grateful.

I have also to express my obligation to the late Sir William Herschel, and to Dr. Locard of Lyons, for the specimens of finger-prints reproduced in Chapter XI.

Lastly, I am indebted to Mr. T. J. Ward for preparing some of the excellent photomicrographs of various ink lines and pencil markings and for the illustration of his photomicrographic device; also to Miss M. B. Elliott, M.B.E., for help in illustrating and indexing the book.

C. A. M.

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87 SOUTH LAMBERT ROAD,
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DOCUMENTS, AND THEIR SCIENTIFIC EXAMINATION.

CHAPTER I.

PRELIMINARY EXAMINATION: APPARATUS.

THE term "document" as used in this book signifies an object upon which characters have been written, drawn, or printed, and which is of such dimensions that it can be produced in court as an exhibit. The examination of documents may thus include writing or printing upon paper, wood, or any other material, marking upon linen, or the accidental imprints of a finger upon the pages of a book. As subsidiary to the examination of the object itself, it is frequently necessary to take into consideration the instruments or materials with which the characters may have been produced, and to be familiar with the composition of inks and pencil pigments, and the structure of pen-nibs and metal type.

In the majority of cases documents submitted for scientific examination have a basis of paper, and, although instances where other materials have been used are referred to in these pages, most of the methods and results described are concerned with the more common type of material.

A point of the utmost importance for evidence is to know whether any portion of the document or of the characters upon it show indications of anachronisms. For example, the structure of the material itself may be incompatible with the date upon which a document purports to have been written, or the nature of the pencil pigment or the ink upon a document may not be consistent with the pigments which were in use at the time alleged. For this reason an attempt has been made to fix the approximate dates at which the various materials and writing implements first came into use, and these points are discussed at the beginning of the respective chapters.

Preliminary Examination.—A note should first be made of the date of receipt of the document, and the date should be prefixed to all notes subsequently made concerning it. As a rule, scientific witnesses are allowed to refer to entries in their note-books in Court, provided that these are the original notes made at the time of examination, and that they are only used to refresh the memory as to detail, and not to supply information that has been entirely forgotten.

A preliminary examination should include a description of the document, its dimensions, a record of any obvious peculiarities, and notes upon the characteristics of the paper and pigments, so far as they are discoverable with the naked eye or a lens. For example, the paper may have a distinctive water mark, or may show indications of erasures when examined by transmitted light, or one part of the characters may overlap another and thus afford evidence of prior writing.

In most cases it is advisable to make a photographic record, and the size of this in relation to the original should always be noted.

Photographic Reproductions.—An ordinary folding camera with an anastigmatic lens may frequently be adapted for the purpose, but, as a rule, does not permit of sufficient extension for copying documents. In such cases the best method is to fix an attachment which

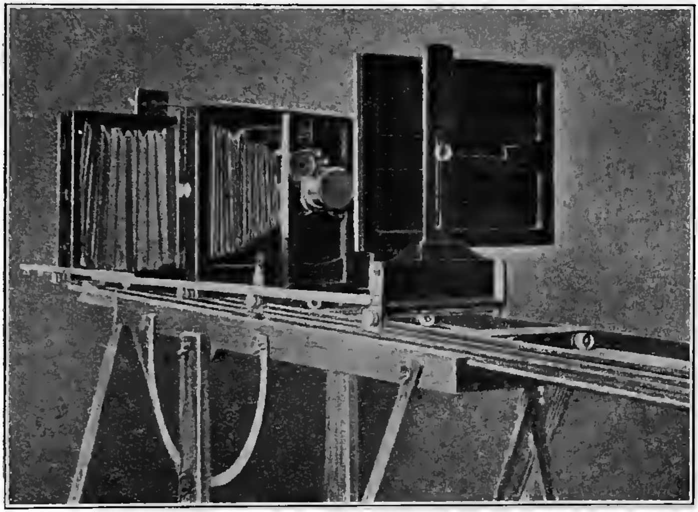


Fig. 1.—Kinsley's Document Camera.

fits into the back of the camera and has a groove at the other end to receive the focussing screen and the plate carrier.

Several simple devices for moving the camera nearer to, or further from, the document without altering the position laterally, may be obtained from the makers of photographic apparatus. Essentially these consist of a long flat board with guides, within which runs a support to which the camera is screwed. At one end is fixed a vertical board at a right angle to the base board, and this easel is provided with wire attachments for keeping a book open with its pages flattened out, or for fixing a document in position.

Another simple apparatus was that originally devised by T. C. Hepworth for downward photography. This consists of a rigid triangular stand with an enlarged open top adapted to support the camera with its lens directed vertically downwards. At a suitable distance beneath the camera is fixed a horizontal support of glass, upon which the document is placed, whilst a mirror, inclined at a suitable angle below this, reflects the light upwards, and thus enables a photograph to be taken by transmitted light.

Various methods for finding the necessary distances between the lens and the document and the lens and the plate have been devised, one of the most simple of which is that outlined in *The Photo-Miniature*, 1902, iv., No. 41, p. 213. A "reduction figure" is first obtained by dividing the size of the original by the size of the required copy. For example, the reduction figure for reducing a document 12 inches long to 4 inches is $\frac{12}{4} = 3$.

The distance between the lens and original is then found by multiplying the focal length of the lens by the reduction figure, and adding one focal length to the sum; whilst the required distance between lens and plate is obtained by dividing the focal length of the lens by the reduction figure and adding one focal length.

In like manner, in making enlargements the same rule is applied, but the "reduction figure" will now be a fraction. For example, in enlarging a 4-inch document to 12 inches the value will be $\frac{4}{12} = \frac{1}{3}$.

Exposures for Focal Extension.—In using a camera with the lens extended beyond the distance corresponding with the lowest *f* number on the mount, the time of exposure is increased in proportion to the square of the length of extension. The real value of the working aperture may be obtained by multiplying the *f* number upon the lens mounting by the focal extension, and dividing the result by the focal length of the lens. For example, when using the stop *f* 16 with a 6-inch lens extended to a distance of 8 inches from the plate, the true working aperture is $f\frac{16 \times 8}{6}$ or $f\,21\frac{1}{3}$.

Watkins' Method.—A simple method of finding the exposures corresponding to different focal extensions is that devised by Watkins. A graduated wooden rule is cut to the same length as the focal length of the lens, and a note taken of the number of lengths of the rule between the lens and the document when a copy is required of any size up to that of the original. The correct time exposure at normal extension is then found by reference to a table, and this value multiplied by a factor gives the exposure required. Similarly, in making a direct enlargement, the number of lengths of the rule between the lens and the plate is measured, and the factor for multiplying the exposure at normal extension is obtained from a second table. The following table gives some of the principal values for copying documents upon a reduced or enlarged scale :—

Watkins' Table of Relative Exposures for Photographic Documents.

A. Reduced Scale.

Number of focal lengths between lens and document.	2	2.2	2.4	2.6	2.8	3.0	3.5	4	5	6
Relative exposure compared with that with lens at normal extension.	4	3.26	2.93	2.64	2.42	2.25	2	1.76	1.56	1.44

B. Enlarged Scale.

Number of focal lengths between lens and plate.	2	2.2	2.4	2.6	2.8	3.0	3.5	4	4.5	5	5.5
Relative exposure compared with that with lens at normal extension.	4	4.84	5.76	6.76	7.84	9	12.25	16	20.25	2.5	29.2

Colour - Sensitive Plates and Screens.—The use of colour screens with colour-sensitive plates is essential for the photography of the details of certain documents; especially in the case of writing in blue or violet pencil pigments, or when the paper itself is of a yellow tint. For example, the writing in copying-ink pencil pigment on the wooden stave (p. 136) required the use of a yellow screen and an appropriate plate to obtain a satisfactory result. This method is also useful in certain cases for demonstrating differences between certain kinds of ink which appear of the same tone upon paper.

Photography beneath Ruled Squares.—The method of photographing portions of documents beneath a glass plate ruled with uniform squares was introduced by Osborn, and has been found particularly useful for demonstrating the points of correspondence of lines on different documents, or of the details of finger prints. These plates of glass are accurately ruled into squares from $\frac{1}{32}$ inch upwards, and, if the negative is enlarged and the squares numbered, it is a simple matter to locate the points of resemblance and difference. This method was used by Osborn to demonstrate the coincidences in signatures forged by copying in the Rice-Patrick case (p. 150), and for the locating the points of resemblance in finger prints (p. 198). One of the most useful sizes measures 1 inch by $\frac{2}{50}$ by $\frac{1}{50}$ inch. The inch is graduated in 50ths, so that it gives readings of twenty-thousandths, the $\frac{2}{50}$ is in 250ths, giving readings of four-thousandths, and the $\frac{1}{50}$ in 500ths, reading two-thousandths, and it is possible to measure from any part of the inch into the more finely graduated field.

Microscopical Examination.—The examination of a document with a lens will frequently reveal details which would escape the notice of the unaided eye. Such preliminary examination is useful, for instance, in studying the colour of the ink in writing, or noting at what points writing in ink or pencil may intersect. It should always precede microscopical examination under a higher magnification. The compound ocular lens of a microscope with the eye-piece removed is well suited for this purpose.

Microscopes for Examining Documents.—For examining the structure of paper, the pigments in pencil writing, and the colorations produced in tests applied to inks, any good compound microscope is suitable, provided there is sufficient room upon the stage to take the document, which is not always the case. For the ex-

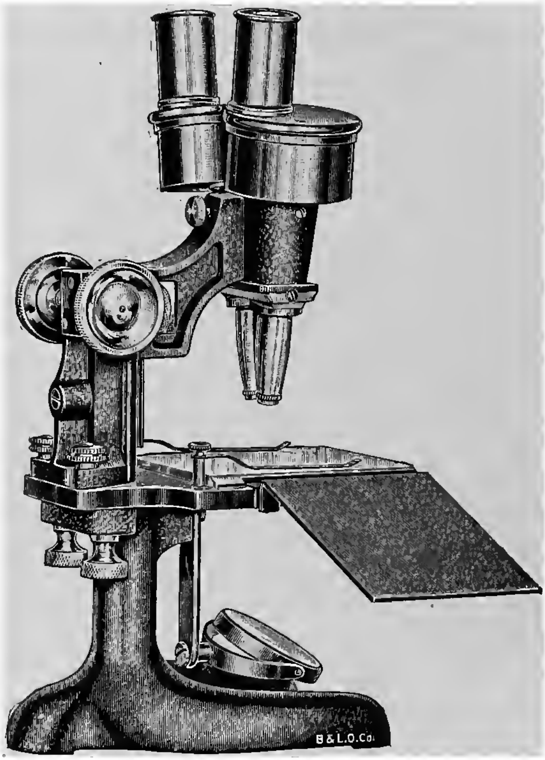


Fig. 2.

amination of large surfaces, however, it is necessary to provide an arrangement whereby all parts of a document can be brought into the field without doubling the paper. In certain types of instruments this is done by arching the supporting pillar backwards, so as to leave room for much more play upon the stage. Other microscopes are constructed in such a way that the entire arm with body tube can be removed and fixed upon a separate

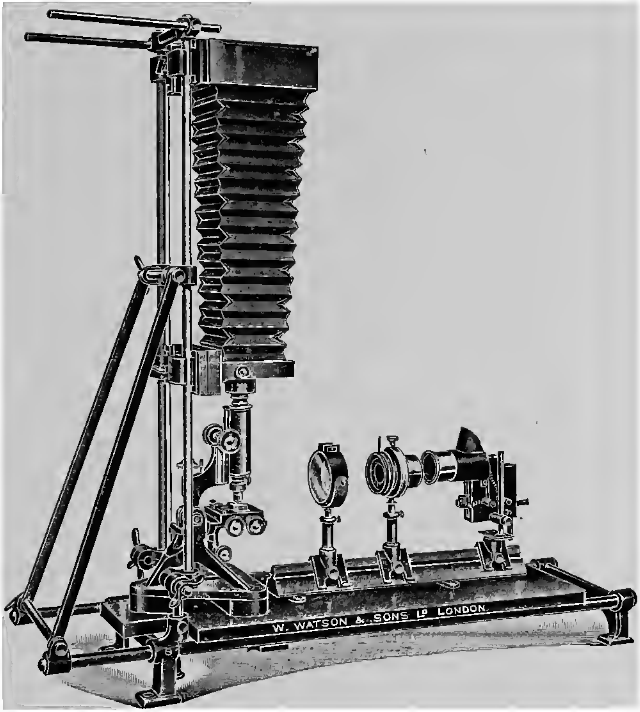


Fig. 3.—Watson's Duplex Photo-micrographic Camera.

stand, which enables it to be moved over any portion of a wide surface.

Binocular Microscopes.—For the examination of certain details, such as indentations in paper or imitation water-marks, the use of the binocular microscope has the advantage of showing the image in its true position and not inverted as with the ordinary microscope, while it also gives a stereoscopic effect. In one type of binocular microscope made by Bausch and Lomb (Fig. 2) the body tube can be fixed upon a separate stand, as mentioned above. For the examination of documents by transmitted light, this instrument may be placed over the document on a box which has a ground glass top, and within which is placed a powerful electric light, such as a Nernst lamp.

Photomicrography.—For many purposes, such as the photography of ink lines or pencil marks, the ordinary microscope, used vertically, with the usual bellows attachment carried in an upright frame gives satisfactory results (Fig. 3), but, in other cases, as, for example, where transmitted daylight is to be the source of illumination, it is preferable to use the camera in a horizontal position.

Ward's Apparatus.—The simple method devised by T. J. Ward[1] has the great advantage of not requiring the use of any complicated apparatus.

The camera is fitted with a short focus lens, whilst a lens of large diameter, the size obviating distortion, is placed between the camera lens and the object. This will enable a magnification of about $\times 8$ to be obtained. For higher magnifications (up to $\times 40$) the camera lens is replaced by a microscope objective fitted into a cork. Magnifications up to $\times$ 400 may be obtained by placing a microscope horizontally, with its eyepiece against the lens mount of the camera, which in this case is used without

[1] *Analyst*, 1920, xlv., 130.

a lens. This communication also gives directions for illuminating the object, and an exposure table.

Measuring Devices.—Various instruments are required for making accurate measurements in the examination of documents. For the measurement of lines and spaces a series of glass rules graduated in fractions of an inch will be found useful, as was first suggested by Osborn.

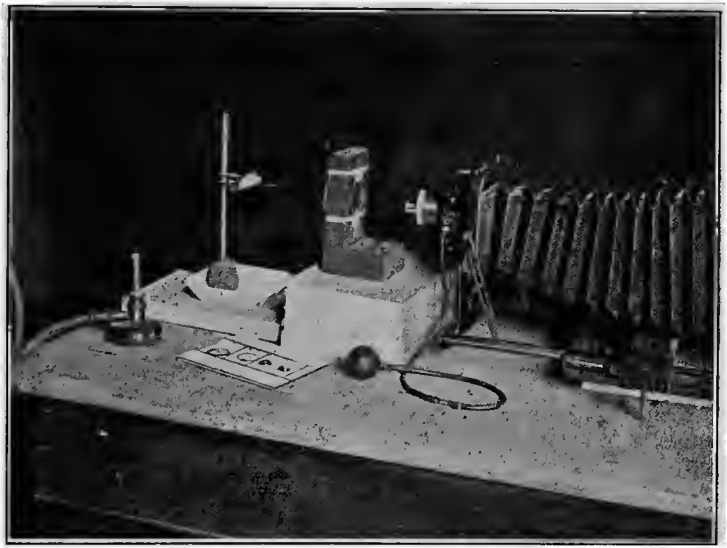


Fig. 4.—Ward's Apparatus.

The angles in writing, etc., are most conveniently measured with a celluloid protractor, which is placed over them.

The Kew micrometer, a diagram of which is shown in Fig. 5, is another exceedingly useful little instrument for the accurate measurement of lines and spaces, and

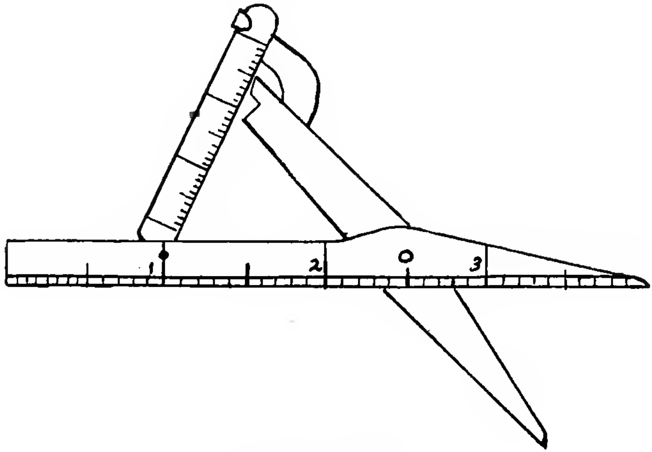


Fig. 5.—Kew Micrometer.

attention has been drawn by Faulds to its value for making comparative measurements of the details of finger prints.

For microscopic measurements a micrometer disc

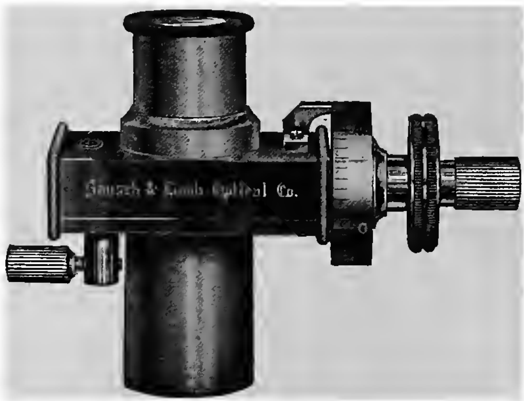


Fig. 6.—Filar Micrometer.

upon which lines are ruled with a diamond may be fitted into the ocular lens of the microscope, whilst for still more accurate work a filar micrometer (Fig. 6) is used. In this device a movable wire is carried upon a slide controlled by a micrometer screw, one complete turn of which moves the wire 0·5 mm. across the field. By adjusting the drum head of this screw, measurements of 0·001 mm. (= 1) can be made. Through the centre of the field passes a fine line, by means of which the position of the object under the microscope in relation to the direction of motion of the moving wire is determined. The eye-piece can be focussed upon the movable wire and a graduated scale in the field.

Measurement of Colour.—It is of the greatest importance to be able to keep a record of the colour of pigments upon documents, especially in estimating the age of inks in writing. One method of doing this is to prepare a series of colour strips with aniline dyes, and thus to match the shade of the pigment in question under the microscope. This method, however, is tedious, since it involves the preparation of a large number of colour standards varying only slightly in tint, and it has the further drawback that the standards themselves do not resist the action of light, and so do not afford a permanent record. It is, therefore, advisable always to compare such colour standards with the standard glasses of Lovibond's tintometer.

Lovibond's Tintometer. — This instrument consists essentially of a long dark box through which light is transmitted, and the lower part of which is divided into two portions, below one of which is placed the object under examination, whilst the other receives a holder containing standard glasses. These glasses are graduated in series of red, yellow, and blue, and are so adjusted in relationship to each other that it is possible to match any tint, and to keep a record of the colour.

It has been shown by Baker and Hulton [1] that for the results obtained by different observers with this instrument to be concordant, it is necessary for certain conditions to be observed, but these apply more particularly to the examination of transparent liquids.

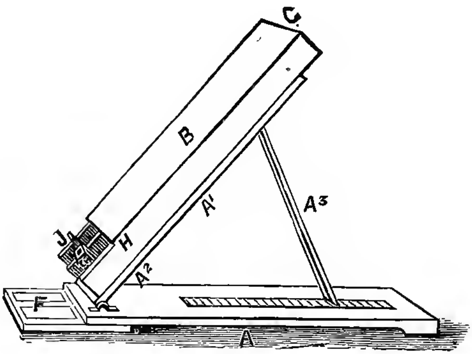


Fig. 7.—Lovibond's Tintometer.

Osborn's Comparison Microscope.—The microscope shown in Fig. 8 enables a direct comparison to be made between the colour of a pigment on a document and a pigment upon another paper, or between the object and Lovibond's tintometer glasses, which for this purpose are inserted into a slot (closed by a shutter) in either of the body tubes. Essentially, this instrument consists of two long body tubes, each of which is provided with its own objective. The light reflected into these tubes

[1] *Journ. Inst. Brewing*, 1907, xiii., p. 26.

brought by means of prisms in the prism box at the
p into one field, with the result that each half of the

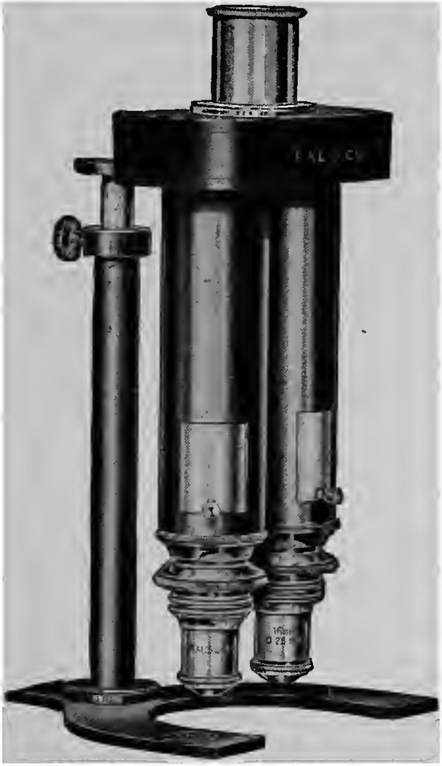


Fig. 8.—Osborn's Comparison Microscope.

eld appears adjacent when viewed through the single
ye-piece.

BIBLIOGRAPHY.

Gross, H.—*Handbuch der Untersuchungsrichter als System der Kriminalistik*, Munich, 1908.

Jago, W.—*Forensic Chemistry and Chemical Evidence*, London, 1909.

LUCAS, A.—*Legal Chemistry and Scientific Criminal Investigation*, London, 1920.

LUCAS, A.—*Forensic Chemistry*, London, 1921.

MITCHELL, C. A.—*Science and the Criminal*, London, 1911.

NICEFORE, A.—*La Police et L'Enquête Judiciaire*, Paris, 1907.

OSBORN, A. S.—*Questioned Documents*, Rochester, U.S.A., 1910.

REISS, R. A.—*La Photographie Judiciaire*, Paris, 1903. *Manuel de Police Scientifique*, Paris, 1911.

WILLS.—*Circumstantial Evidence*, London, 1912.

CHAPTER II.

EXAMINATION OF THE PAPER.

istorical Outline.—A scientific examination of the ɩper or other material forming the basis of a document ay be of the greatest importance, especially in the case antique manuscripts or early title deeds, since it is ɔt altogether an easy matter for a forger to avoid the tfalls of anachronisms in some of the numerous details. is for this reason that a knowledge of the approximate ɩtes of the use of various materials in the manufacture paper is particularly valuable.

Papyrus.—Although papyrus was used in Egypt as a riting fabric at a very early period, the earliest fragents known date to a period about B.C. 3500. Pliny[1] ves a description of the method of preparing the sheets om the papyrus plant. The fibrous material from the em was cut into strips which were placed side by side ; ɔon them were glued similar strips at right angles, the ɩeets being then pressed and dried in the sun.

Greek papyri, dating from B.C. 270 to A.D. 680, have ɜen found in Egypt, whilst other relatively modern ɩpyri of Greek origin have been found at different mes in excavations at Herculaneum.

Parchment and Vellum.—According to Kenyon[2] all ɩe evidence points to the transition from the use of ɩpyrus to that of vellum having taken place in the

[1] *Natural History*, xiii., p. 11-13.

[2] *The Palæography of Greek Papyri*, 1899, p. 121.

fourth century of the present era, although the earlier material continued to be used occasionally for a century or two later.

One of the earliest examples of vellum manuscripts to be seen in the British Museum is the MS. known as *The Lindisfarne Gospels* or *The Durham Book*, the date of which is supposed to be about the end of the seventh century. Parchment, prepared from the skins of sheep and goats, was a coarser material than vellum; it is still used as the writing material for title deeds and other legal documents.

Vellum was gradually displaced by paper, the early material for which appears to have been linen rags.

Paper.—As in the case of so many other inventions, the origin of paper-making has been traced to the Chinese, although its immediate introduction into Europe appears to have come through the Arabs by way of Spain in the early part of the twelfth century.

Linen Paper.—Documents on linen paper which are supposed to date back to the close of the eighth century A.D., have been found in Egypt, and many of the early MSS. in oriental languages are on paper made of linen. Paper was first made from rags in Germany early in the fourteenth century. One of the earliest specimens of linen paper in England is an inventory in the library of the Dean and Chapter of Canterbury of the goods of Henry, Prior of Christ Church, who died in 1340.[1]

Lucas mentions that genuine Arabic legal documents dating from 1723 to 1870 have been found to consist entirely of linen.[2]

[1] Astle, *Origin and Progress of Writing*, 1803, p. 206.
[2] *Legal Chemistry*, p. 70.

Cotton Paper.—At a later period the use of paper ade from cotton rags, or a mixture of cotton and linen, ecame general in certain localities. In Eastern countries otton paper, called *charta bombysina*, was known as far ack as the ninth century, and was commonly employed Spain about the beginning of the thirteenth century. otton paper was but little used in Italy, with the excep- ion of certain ports, such as Naples, in communication ith Greece. Hence a Greek charter, purporting to be f the tenth century, written on cotton paper might be enuine, whereas a Latin charter upon the same material ould be open to suspicion.[1]

Straw, Wood Pulp, etc.—Various materials, such as traw, nettle fibres, and so on, were tried experimentally or the manufacture of paper, but rags continued to be he principal raw material until about the middle of st century.

According to Sindall[2] straw was first used on a large cale about 1850. Wood pulp. manufactured by Keller's rocess, was first employed in 1840, soda-wood pulp bout 1854, and sulphate wood pulp, made by Tilgh- ann's process, in 1860.[2]

It was not until about 1870-80, however, that echanical wood pulp became a common paper material, hilst the general use of wood cellulose dates from bout 1880.[3]

In one case, recorded by Lucas, an Arabic document ated 1213 A.H. (A.D., 1798) was composed of wood ellulose, which at that date had never been used for aper manufacture.[4]

1 Astle, *loc. cit.*, p. 205. 2 *Paper Technology.*

3 *Deterioration of Paper, Journ. Soc. Arts*, 1898.

4 *Legal Chemistry*, p. 70.

Esparto was first used as a paper material in this country about 1860.[1] Chlorine was first used for bleaching paper in 1814.

Early Manufacture.—Until about the period 1799 to 1810, when machinery began to take the place of hand labour, the process of making paper was essentially the same as had been in use for centuries. Rags of linen or cotton and linen were sorted, cut up, washed with water, and left to ferment in closed vessels for several weeks, until a pulpy mass was obtained. This was beaten in oak vats with stamping rods fitted with iron heads and worked either by hand or by primitive mills. The pulp was spread evenly upon wire moulds, upon which was then placed a mahogany frame termed the "deckle," and subsequently transferred to a layer of felt. After being repeatedly pressed, it was sized and given a final pressing.

No paper was made in England prior to about 1493, about which time a mill was set up by John Tate at Stevenage in Hertfordshire. The first book printed on this paper was *Bartholomæus de Proprietalibus Rerum*, by Wynkin de Worde, about the year 1494.[2] Subsequently a mill was established in 1588 at Dartford by John Spielmann, a German, who was jeweller to Queen Elizabeth.[3]

Blotting Paper.—References are found to blotting paper as far back as 1465, and fragments of blotting paper have been discovered in account books of about

[1] *Paper Technology.*

[2] *Gentleman's Mag.*, 1788, p. 874.

> "John Tate the yonger joye mote he broke,
> Which late hathe in England doo make this paper thynne,
> That now in our English this boke, is printed inne."

[3] *Ibid.*, p. 784.

that period.[1] Sand continued in general use as a blotting agent, however, until well into last century, and is still used in out-of-the-way places.

Water Marks.—Important evidence as to the genuineness of a document has frequently been afforded by the character of the water mark in the paper. Although some of the earliest papers show no water marks, the use of such special devices was adopted as a distinctive mark at an early date.

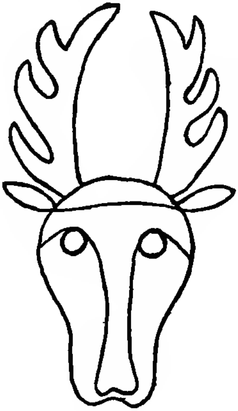


Fig. 9.

Fig. 10.

A very interesting collection of the old water marks on papers in the Record Office was made by Richard Lemon, many of which have been published. The writer is indebted to Dr. Henry Scott for permission to reproduce the accompanying specimens. The earliest water mark in the Lemon collection is the stag's head (Fig. 9), which is a tough paper of the year 1340; this is only 39 years later than the earliest known water mark. The duck

[1] *Historical Documents*, p. 59.

(Fig. 11) is about a century later, whilst the dragon and the dachshund (Figs. 10 and 12) are in sixteenth century papers.

Pot paper (1540 to 1560) was so called from being marked with different forms of drinking vessels, whilst post paper (introduced about 1570) received its name from the crowned post-horn which was originally its distinctive mark. The original water mark of foolscap paper was a crown, which Cromwell changed into a fools' cap; by an oversight this was continued after the

Fig. 11.

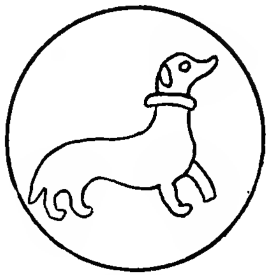


Fig. 12.

Restoration, but was afterwards changed to a figure of Britannia.

The first book printed upon English paper, in 1495, shows the water mark of John Tate—an eight-pointed star within a double circle. The paper upon which the first edition of Shakespeare was printed in 1623 has the water mark of a cap resembling a jockey's cap.[1] Caxton's book, "The Game of Chesse," has a water mark in the form of a "P."

A series of three crescent moons as a water mark

[1] R. Herring, *Paper and Paper-Making*, 1855, p. 80.

occurs in old Egyptian documents, and has been observed in paper of 1774.[1]

Cases in which abnormal water marks have been observed have frequently raised a presumption of fraud, although, as a rule, the point is too well known to prove a pitfall to a practised forger.

In the notorious Ireland forgeries of Shakespearian MSS. the spurious writings were produced upon the fly leaves of Elizabethan books, having the correct water mark of a jug.

Several instances of anachronisms in water marks are recorded by Wills in his *Circumstantial Evidence*, as, for example, in a case in which a letter alleged to have been sent from Venice was thus proved to have been written upon paper made in England at a subsequent date.[2]

More recent cases are cited by Lucas.[3] In one of these it was found that two receipts, dated three months apart, had originally formed part of the same sheet of paper, since the torn portions of the water marks coincided, whilst in a similar case there was an interval of twelve months between the dates of receipts written upon two portions of the same sheet of paper.

The evidence of the water mark, however, is not always conclusive as to the date of the paper, since manufacturers may intentionally use moulds of a wrong date. Thus, in a trial heard in Edinburgh in 1834, evidence was given by the paper manufacturers that they were post-dating their paper, and were using moulds with water marks of 1828 pattern to supply a special order.

[1] Lucas, *Legal Chemistry*, p. 70-71.

[2] *Circumstantial Evidence*, 4th Ed., 1862, p. 141.

[3] *Loc. cit.*

Imitation Water Marks.—Several instances of imitation water marks produced in the paper subsequent to its manufacture have come within the writer's experience. The normal water mark formed in the manufacturing process is obtained by the use of a wire device fixed to the surface of the fine wire gauze of the mould or dandy roll so that the increased pressure upon the pulp at this point renders the paper more transparent.

In forging a water mark, therefore, it is necessary to use certain means to render the paper more transparent. Sometimes this is effected by the use of a stamp with carnauba wax or spermaceti and a drying oil, and, in such cases, the transparency may be reduced by treating the place with a solvent for fats such as ether. Oil of turpentine mixed with Canada balsam is also said to be used for this purpose. By moistening the suspected place with a dilute solution of potassium hydroxide it is sometimes possible to remove such a water mark, whereas a genuine mark will be unaffected by such treatment.

Artificially Aged Paper.—Lucas [1] records several instances where documents have been scorched or creased, torn, and smudged with dirt and grease to make them appear old. In such cases he has frequently observed streaks or lines produced by the dirt having been applied artificially.

The so-called "foxy" appearance of paper caused by the oxidising action of mould fungi or chemical processes of oxidation could not be easily imitated so as to deceive a chemist, but artificial staining with a weak extract of tea is said to have been used for the

[1] *Legal Chemistry*, p. 72.

purpose. Lucas points out that these spots, when natural, become more or less transparent on treatment with water, regaining their original appearance after drying.

In the forgeries made by A. H. Smith (1891) of letters of Burns, Scott, Thackeray, and other celebrities, blank leaves of paper of the periods were used in each case. These showed numerous worm holes, consistent with their age, but suspicion was first aroused by the fact that in every instance the worms had been careful to avoid the writing.[1]

Thickness of Paper.—A rapid sorting test for determining whether pieces of paper could have been derived from a single sheet is afforded by measuring their thickness. For this purpose micrometer calipers provided with a vernier reading to ten-thousandths of an inch are convenient instruments.

Osborn[2] gives the following measurements for sheets of typical kinds of paper :—Japanese tissue (calendered), 0·0009 ; ordinary tissue, 0·0014 ; light typewriting, 0·027 ; heavy note, 0·0071 ; average visiting card, 0·0182 ; and forty-ply card, 0·0763 inch. He also shows that by means of this test alone it is possible to classify ordinary writing paper in upwards of sixty groups. The average variation in the thickness of sheets from the same packet was but slight. For example, thin papers showed an occasional variation of one ten-thousandth in a maximum thickness of twenty-three ten-thousandths of an inch, and thick paper an occasional variation of five ten-thousandths in a maximum thickness of seventy-two ten-thousandths of an inch.

[1] D. Blackburn and C. W. Caddell, *The Detection of Forgery*, 1909, p. 56.

[2] *Questioned Documents*, p. 364.

Microscopical Examination.—A direct microscopical examination of paper in its compact form is not an easy matter, since the field shows a tangled mass in which it is practically impossible to identify the separate constituents. It has been found possible, however, under certain conditions to stain some of the components differentially, and then to recognise them in petroleum spirit (benzine). For this purpose Kollmann [1] moistens small fragments of the paper in water and then immerses them for six hours in 0·1 per cent. solutions of Capri blue and erganon violet, after which they are thoroughly washed with water, dried, and examined in benzine. Under these conditions the fibres of the paper remain practically undyed, whilst the secondary constituents (filling materials, free rosin, resinates, alumina, starch) are frequently dyed and rendered distinctly visible. To distinguish between loading materials and sizing substances two portions of the same material are dyed, before and after the removal of sizing substances and aluminates (1) by extraction with hydrochloric acid, (2) with alcohol and ether successively, and (3) with all three solvents.

If the paper is dyed first with erganon violet and then with Capri blue, alumina compounds will be coloured violet and kaolin blue.

The table on the opposite page shows the results obtained by this method.

Separation and Identification of Paper Fibres.—The identification of the fibres composing the paper of a document is frequently of extreme value in detecting forgery. In preparing specimens for microscopical

[1] *Der Papier Fabrikant*, 1914, xii., p. 241.

Dye.	Ordinary Paper.	Ether-extracted Paper.	Acidified Paper.	Completely De-sized Paper.
Capri blue.	Fibres undyed except individuals, many intense blue amorphous elements.	Do.	Do.	Do.
Erganon violet.	Many very pale violet, rarely intense, violet amorphous elements.	Intense violet amorphous elements,	Very pale rose; many amorphous elements.	Individual pale or orange-yellow amorphous elements.

examination a small portion of the paper is treated with a 5 per cent. solution of sodium hydroxide to remove sizing, and then boiled with the dilute alkali. The resulting pulp is washed, a small portion teased out on a slide, a cover glass pressed down upon it, and the fibre examined under a $\frac{1}{4}$-inch objective. During the boiling with sodium hydroxide the presence of mechanical wood pulp is indicated by the production of a yellowish coloration, whilst fibres free from wood remain uncoloured. In the case of unsized paper, water alone is used for the boiling process, whilst parchment paper may be disintegrated by boiling with dilute (1 : 1) sulphuric acid.

Staining the Fibres.—The use of staining reagents facilitates the recognition of the different fibres. The reagents most commonly used are :—

(1) *Iodine in Potassium Iodide Solution.*—This consists of 1·15 grms. of iodine, 2 grms. of potassium iodide, 2 c.c. of glycerin, and 20 c.c. of water.

2. *Zinc Chloride and Iodine Solution.*—(A) 20 grms. of anhydrous zinc chloride in 10 c.c. of water. (B)

Iodine, 0·1 grm.; potassium iodide, 2·1 grms., and water, 5 c.c. The two solutions are mixed and the clear liquid decanted.

Herzberg [1] classifies the more common types of paper fibres into the following groups in accordance with their behaviour in these tests:—

		Iodine and Potassium Iodide.	Zinc Chloride and Iodine.
GROUP I. Lignified Fibres.	Mechanical wood pulp. Jute. Fibres containing undissociated cellulose.	Fibres yellow to yellowish-brown according to thickness and degree of lignification.	Fibres pale to dark yellow.
GROUP II. Cellulose.	Straw cellulose. Jute cellulose.	Grey.	Blue to bluish-violet.
	Wood cellulose. Andansonia.	Grey to brown.	Blue to reddish-violet.
	Esparto.	Some grey, others brown.	Blue and bluish-red.
	Manila hemp.	Fibres grey, brown and yellowish-brown.	Blue, bluish-violet, red violet, dirty yellow, greenish-yellow.
GROUP III.	Linen, hemp, cotton.	Pale to dark brown, in thin layers, almost colourless.	Pale to dark bluish-red.

Characteristics of Individual Fibres.—The linen and cotton fibres in old rag paper may be readily identified by their characteristic forms, although some will be more or less disintegrated.

[1] *Papierprüfung*, 1915, p. 94.

Cotton is characterised by its long flat ribbon-like strands, showing here and there, when the fibres were ripe, distinctive twists (see Fig. 13). Unripe cotton contains few of these twists, whilst the so-called "dead" cotton appears as a thin structureless rod.

Linen (flax).—The fibres are long and round, and are characterised by frequent joints resembling the knots in a bamboo cane (Fig. 14).

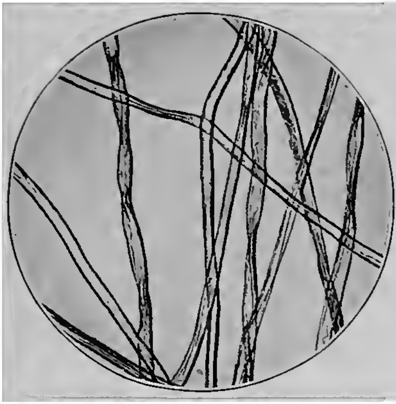


Fig. 13.—Cotton.

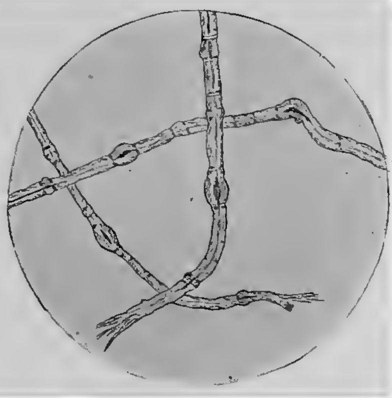


Fig. 14.—Linen.

Hemp is very similar to flax, but the fibres are frequently associated in bundles, and show parallel striations. As a rule, the central canal or medulla is not visible (Fig. 15).

Manila hemp fibres are of wider diameter than hemp, and show a distinct medulla. The curious connected structures (Fig. 16) may sometimes be seen.

Jute fibres resemble hemp in being frequently associated in bundles. The medulla appears to vary considerably in diameter in different parts of the fibre

(Fig. 17). This is caused by variations in the thickness of the cell walls.

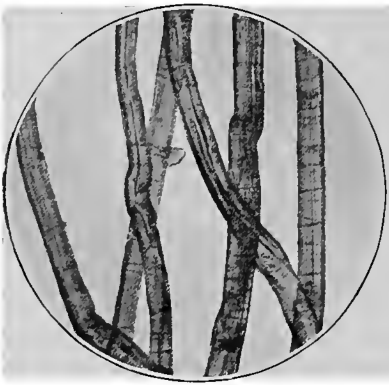


Fig. 15.—Hemp.

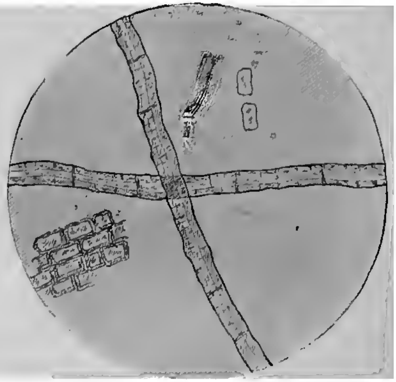


Fig. 16.—Manila.

Wood Pulp.—The wood most frequently used is derived from various species of conifers, such as *Pinus excelsis*, *P. silvestris*, and *Abies pectinata*, the anatomical structure

Fig. 17.—Jute.
Showing Bundles.

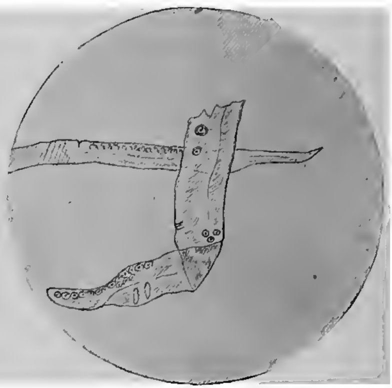


Fig. 18.—Pine Wood

of which is very similar. They are characterised by the presence of pores which usually appear as two concentric rings. Some of the so-called "wood-cells" containing these pores have thick, and others thin, walls. Occasionally the thin transparent ribbons in wood pulp show a twisted structure resembling that of cotton, and have surface markings resembling a lattice (Fig. 18).

Poplar wood cells may be distinguished from pine wood by their honeycomb structure (Fig. 19.)

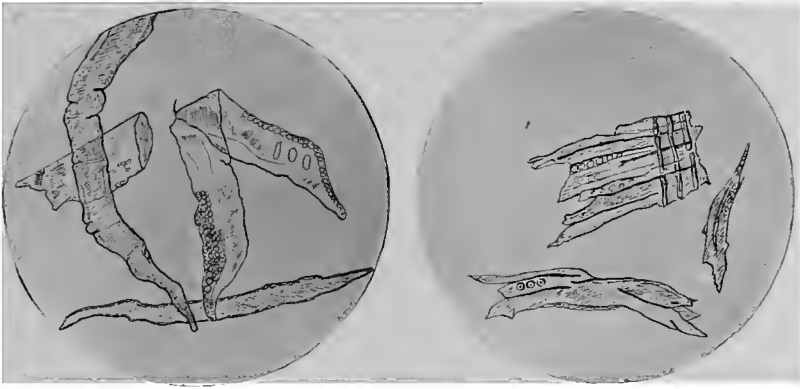


Fig. 19.—Poplar Wood.
Showing Vessels.

Fig. 20.—Mechanical Wood.
Showing Pores and Medullary Rays.

Mechanical wood pulp shows masses of ribbons in which the distinctive pine wood pores may be seen, whilst many of the fibres are coated with incrustations (Fig. 20).

Esparto is characterised by the presence of cells with serrated edges and fine hairs resembling teeth in form. The fibres are short and smooth, and have pointed ends and a small medulla (Fig. 21).

Straw fibres differ from esparto in having a curious jointed formation. They are more pointed and have a wider medulla. Cells with serrated edges similar to

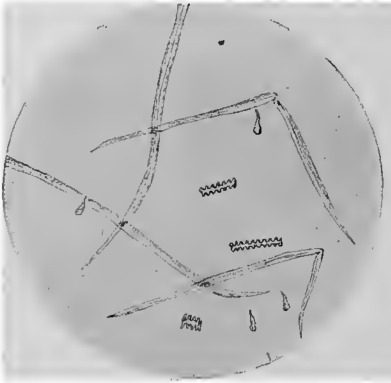


Fig. 21.—Esparto.
Showing Hairs and Serrated Cells.

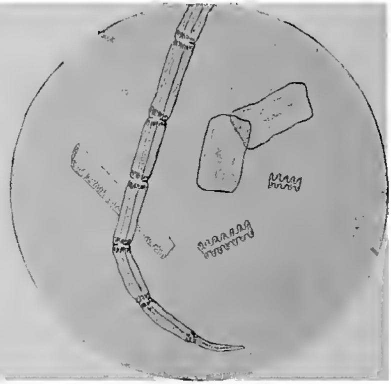


Fig. 22.—Straw (highly magnified).
Showing Oval and Serrated Cells.

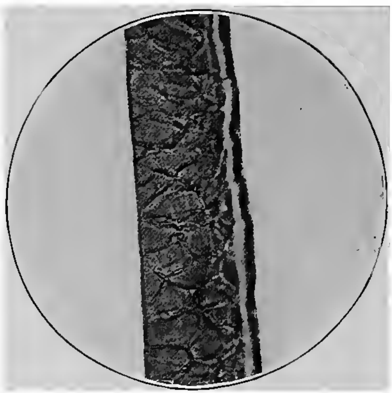


Fig. 23.—Wool (highly magnified).

those of esparto may be seen, but there are also characteristic oval cells which are not present in esparto.

Cells in the form of rings and spirals are also occasionally present, but the small hairs which are distinctive of esparto are never found in straw (Fig. 22).

Wool fibres are used in the manufacture of grey filter papers. They are usually characterised by their scaly surface, although in some cases the surface may have been denuded of scales (Fig. 23).

Chemical Examination of Paper.—Papers frequently show distinctive chemical differences in the amount of mineral matter, pigment, and the nature of the sizing, and it may thus be found possible to distinguish between different documents by means of chemical tests.

Mineral Matter.—Ordinary unsized paper, such as blotting or filter paper, is practically free from mineral matter, whereas ordinary sized paper will yield about 2 per cent. of ash, and coloured paper may give considerably more.

The substances used for loading paper include *china clay* (hydrated aluminium silicate), *pear hardening* (calcium sulphate), and *blanc fixe* (barium sulphate), *agalite* (magnesium silicate), and *satin white* (a mixture of alumina and precipitated calcium sulphate). Estimation of the amounts of the additions by the ordinary methods will frequently be of service in detecting forgery, or in identifying two portions of paper of common origin.

The estimation of sulphur in the ash has been utilised by Levi [1] as a very distinctive test. The fused ash is treated with an alkaline solution of lead acetate, and the intensity of the yellow coloration produced is compared with that given by standard solutions. So sensitive

[2] *Zeitsch. angew. Chem.*, 1910, xxiii., 1258.

is this reaction that a perceptible yellow coloration is given by an ash containing as little as 0·000003 grm. of sulphur.

Chlorides are detected and estimated by boiling the paper with water and titrating the extract with standard silver nitrate solution. If present in more than traces, they indicate that the paper has not been sufficiently freed from the products of the chlorine bleaching process.

Estimation of the Sizing.—The sizing materials in common use include *gelatin* or glue, *rosin*, either by itself or in admixture with glue, *casein* (most frequently in coated papers), and *starch*, which is sometimes used as a dressing material in duplicating or other unsized paper.

Gelatin is identified by boiling strips of the paper with water, and testing the extract with a dilute solution of gallotannic acid, which, in the presence of gelatin, gives a flocculent yellowish precipitate.

Rosin is extracted by boiling the paper with pure alcohol. It may then be identified by the Storch-Morawski reaction (red-violet coloration with sulphuric acid and acetic anhydride).

Casein may be detected, in the absence of gelatin, by means of Millon's reagent (solution of mercury in its own weight of fuming nitric acid of sp. gr. 1·4; then diluted with two parts of water). This reagent gives a pink coloration with proteins, such as casein.

In testing coated papers a small quantity is boiled with sodium carbonate solution, and the solution filtered and treated with acetic acid to precipitate the casein, which is then washed and examined.

Starch is readily identified by the blue coloration which it gives with a dilute solution of iodine. When present, it may be estimated by first extracting any rosin by means of alcohol, and drying and weighing the paper; then extracting the starch by means of diastase, and again weighing the residue of dried paper. The difference between the two dried residues gives the amount of starch.

Alum.—In certain cases Hughes' iodine reaction may also aid in the differentiation of two kinds of paper. If a strip of paper is moistened with potassium iodide solution and suspended a gradual liberation of iodine will take place. This has been found by Strachan [1] to be due to undecomposed alum or aluminium sulphate in the paper, and the intensity of the coloration affords a measure of the latent acidity (due to alum) in the paper. Incidentally, it also gives a probable explanation of the rapid deterioration of certain modern written documents.

Artificial Sizing.—It not infrequently happens that a slight erasure may change the whole sense of a letter. For example, in a case within the writer's experience a letter containing the words "our house" was put forward as evidence as to the ownership of the property. When this was examined under the microscope by transmitted light it showed unmistakeable signs of erasure in front of the "our," the sizing having been removed and the fibres scratched up, apparently with the point of a knife. The paper was also more transparent at the place where the erasure had taken place. These facts supported the contention of the other side that the original reading had been "your," and that the "y" had been erased.

[1] *Chem. News*, 1911, ciii., 193.

To lessen the chance of detection from such a trail, skilful forgers have been known to paint the place over with a solution of rosin, so that, superficially, it has the appearance of the rest of the surface of the paper. This dodge may be detected by an examination of the sizing, the patched place being easily stripped by brushing it over with alcohol to dissolve the rosin.

It has been shown by Kitching (*Analyst*, 1922, xlvii., 206) that it is possible to distinguish between different kinds of paper by the appearance of the sizing when examined in ultra-violet light.

Chemical Reactions for Fibres.—Several distinctive tests for fibres have been based upon the reactions of lignin. For example, Wiesner's phloroglucinol test is based upon the fact that fibres containing lignin give a pink coloration when treated with a hydrochloric acid solution of phloroglucinol.

On applying the reagent (prepared by dissolving 5 grms. of phloroglucinol in 125 c.c. of hydrochloric acid and 125 c.c. of water), a coloration indicates the presence of mechanical wood pulp.

Paper containing certain dyestuffs, such as metanil yellow, gives a red coloration with hydrochloric acid, and a test should, therefore, always be made with that acid alone.

The presence of *straw* or *esparto* is indicated by a pink or red coloration when a small portion of the paper is heated with a 10 per cent. solution of aniline sulphate, the intensity of coloration being approximately proportional to the amount of those fibres.

Colouring Matter in Paper.—Better qualities of blue paper are coloured by the addition of various pigments, such as ultramarine, Prussian blue, or smalt, whilst inferior qualities are frequently dyed. Old document paper coloured with ultramarine is bleached by hydrochloric acid, whilst Prussian blue is bleached by alkali.

The presence of ultramarine may be confirmed by the evolution of hydrogen sulphide (detected by lead acetate paper) when the paper is heated with hydrochloric acid. In the case of Prussian blue the colour is restored on acidifying the dilute alkali solution.

Many aniline blue dyes are not affected by acid, whilst others are turned brown by alkali. Tests should be applied to an alcoholic extract of the paper. If the ash from the paper is blue, the pigment was probably smalts (cobalt), which is, however, only used in expensive papers. Its presence may be confirmed by means of a borax bead test.

Yellow papers may contain lead chromate (chrome yellow), or be dyed with auramine, metanil yellow, etc. The dyestuffs may be detected in an alcoholic extract of the paper, and chrome yellow in the ash by the usual tests for chromium and chromates. Chrome yellow may also be present, in addition to ferric oxide, in buff paper.

Brown or green papers are usually dyed, but sometimes contain iron or manganese, or a mixture of chrome yellow and Prussian blue.

Black papers may be dyed with an aniline dyestuff, or may contain iron gallotannate, the presence of which may be detected by the usual tests for iron and gallotannic acid.

BIBLIOGRAPHY.

BLACKBURN, D., and CADELL, C. W.—*The Detection of Forgery*, London, 1909.

BROMLEY, H. A.—*Outlines of Stationery Testing*, London, 1913.

CROSS AND BEVAN.—*Cellulose.*

HERRING, R.—*Paper and Paper Making*, London, 1855.

HERZBERG, W.—*Papierprüfung*, 1915.

KENYON, F. E.—*The Palæography of Greek Papyri*, Oxford, 1899.

KOOPS, M.—*Historical Account of Substances used . . . prior to the Invention of Paper.* [Printed on straw paper]. London, 1800.

LUCAS, A.—*Legal Chemistry and Scientific Criminal Investigation*, London, 1920.

LUCAS, A.—*Forensic Chemistry*, London, 1921.

MATTHEWS, J. M.—*The Textile Fibres*, New York, 1913.

MITCHELL, C. A., and PRIDEAUX, R. M.—*Fibres Used in Textile and Allied Industries*, London, 1910.

SCOTT AND DAVY.—*Historical Documents.*

SINDALL, R. W.—*The Manufacture of Paper*, London, 1908.

SINDALL, R. W.—*Paper Technology*, London, 1906.

WILLS.—*Circumstantial Evidence*, London, 1912.

CHAPTER III.

PENS AND PEN MARKINGS.

Reed Pens.—The use of reed pens for writing dates back to the days of ancient Egypt, for such pens have frequently been found in association with early papyri. The specimens shown in the illustration are exhibited

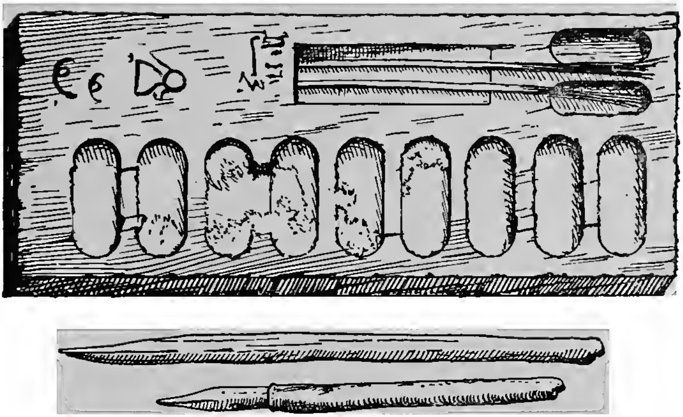


Fig. 24.—Inks, Egyptian Palette, Brushes, and Pens.

in the British Museum, and prove that such pens were in use as far back as 1500 B.C. Later evidence of the use of reed pens is afforded by the account given by Sir Humphry Davy[1] of his examination of fragments of papyri discovered in the ruins of Herculaneum which

[1] *Trans. Roy. Soc.*, 1821, xi., 191.

was overwhelmed by Vesuvius in A.D. 70. The illustrations in his paper include one showing an ink-pot, a reed pen, and a roll of papyrus.

According to Lucas,[1] reed pens are still commonly used in Egypt for Arabic writing, although they are being gradually superseded by a steel pen of special construction.

Quill Pens.—The earliest known reference to the use of quill pens is by Isidore, of Seville, in the early part of the seventh century, whilst collateral evidence that quills were in use at that period is to be found in the MS. known as *The Lindisfarne Gospels* or *The Durham Book*, which is one of the earliest vellum manuscripts in the British Museum. It is noteworthy that the illuminated figure of St. Mark, which precedes his Gospel, holds a pen cut like a quill.

The quill pen became as intimately associated with vellum as the reed pen had been with papyrus, and for many centuries was practically the only writing implement used throughout the Western world.

Steel Pens.—The steel pen was foreshadowed by a few specimens in bronze found in Italy and one in England. which may be seen among the Roman antiquities in the British Museum, but it was not until the 19th century was well advanced that steel pens began to displace the universal quill.

In 1803 Wise's pens were put upon the market. These consisted of metal tubes bent round but not united at the edges, so that a slit was left, whilst the side was cut away to form a point.

The next advance was the production of nibs, which

[1] *Legal Chemistry*, 87.

were patented by Bryan Donkin (Eng. Pat. 3118, 1808). These nibs were cut from quills, or were made of steel, brass, silver, gold, or platinum, and were flat instead of circular in section. They were also made in two halves, which could be fitted into a pen holder.

In 1818 Charles Watt introduced a process of gilding quill pens, whilst, in 1822, Hawkins and Mordan claimed the use of horn and tortoise shell for the preparation of pen nibs.

The modern pen industry, however, was based upon the patent of James Perry (Eng. Pat. 5,933, 1820), in which is described the preparation of pen nibs from hard elastic metal, these nibs having an aperture with which the slit communicated.

Fountain Pens.—The earliest type of fountain pen appears to be that patented by Fölsch and Howard (Eng. Pat. 3,214, 1809), which consisted essentially of a pen of glass, enamel, or metal drawn out to a fine point, and having a hole in the side to promote the flow of ink with which the tube was filled.

Another type of fountain pen was patented by Scheffer (Eng. Pats. 5,105, 4,426) in 1819.

Stylographic pens were not introduced until a comparatively recent date, the first patents being those of Cross (1878) and Mackinnon (1879), which were taken out in the United States.

PEN MARKINGS.

Structure of Pen Strokes.—As is well known, the point of an ordinary steel pen is divided by a slit, and, being elastic, the two parts will separate to a degree depending, to a large extent, upon the pressure applied in writing. Hence, a line which appears upon casual examination to be uniform can usually be seen, upon magnification, to have two outer walls caused by the divided points of the nib having penetrated the sizing of the paper and formed furrows which received more of the ink pigments, and a core between them formed by the ink spreading from the two exterior lines.

The structure of the lines can be seen more readily in the case of writing which has been recently blotted, whilst in old writing it may be made visible by treating the lines with a reagent, such as dilute oxalic acid. This effects a differential bleaching, the surface pigment being removed more rapidly than that contained in the furrows formed by the divided points. It is possible by this means to distinguish between writing done with a quill pen and that produced by a modern steel nib, for a quill pen is much softer and more flexible, and thus produces a more uniform mark upon paper. In some cases it is possible to see differences in the writing caused by the "mending" of the quill before the document was finished. Similarly, it is possible to distinguish between old and modern pen marking, and it is by reason of this distinctive difference that it has frequently been found possible to prove that early writing was not as old as it purported to be. For example, in the case of *Rex* v. *Menzies*, evidence was given that the disputed documents could not have been genuine, since they had been written with a modern pen, whereas the dates they bore were prior to the invention of steel pen nibs.

Analogous characteristics enable the strokes made with a fine pen with divided nib to be distinguished from those made with a stylographic pen. The latter contains a single needle point, kept in position in the tapering point of the pen-holder by means of a spring. The pressure of the needle point upon the paper depresses the spring and allows a little of the ink in the pen barrel to pass on to the paper, whilst on lifting the pen from the paper the spring causes the needle point to close the orifice.

Hence, the mark made by a stylographic pen is a single uniform fairly broad furrow, and, since the effect of the elasticity of the ordinary steel nib is lacking, the lights and shades to be found in the stroke made by an ordinary pen will not be found in stylographic writing.

The structure of the pen stroke will also depend upon the age of the pen nib. In the case of a new nib the strokes will be more uniform, whereas when a nib has become worn by use or corroded by the acid in the ink, one point may be decidedly longer than the other, and thus cause unequal scratching of the paper, so that the ink will penetrate more deeply on one side of the line than upon the other. The presence of such a characteristic as this may frequently be distinctive of a particular piece of writing.

As a rule, it is not possible to distinguish between the marks made with an ordinary pen and with a fountain pen, except in cases where the ink does not flow readily from the latter. In that case the writing may show scratches upon the paper instead of the usual ink strokes at the beginning of passages.

Width of Pen Strokes.—Osborn[1] has shown that the width of pen-nibs, measured at the place where they

[1] *Loc. cit.*, p. 155.

begin to be rounded off to the tip, ranges from about $\frac{1}{25}$th inch in the case of a very broad oblique pen (a so-called "stub" pen) to about $\frac{1}{300}$th inch in the case of the finest "crow quill" mapping pen. The average width of stroke made by the former, with normal pressure and an ink of average fluidity, was about $\frac{1}{30}$th inch in diameter, whilst with the "crow quill" it was about $\frac{1}{330}$th inch. An average coarse pen-nib had a point measuring about $\frac{1}{100}$th inch, and made a stroke not quite so wide.

The accompanying figure shows the difference in

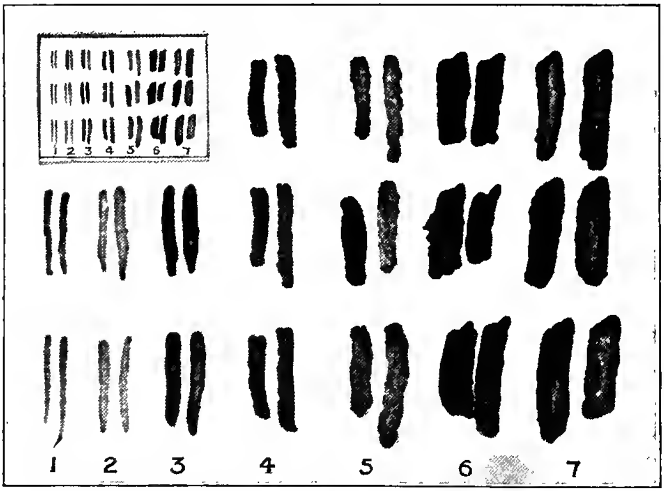


Fig. 25.—Strokes made with various types of pens. Natural size, and enlarged to about $2\frac{1}{2}$ diameters.

1. Mapping Pen.
2. Gillott's "St. George" 202.
3. Gillott's "School" 353.
4. Easterbrook "Relief."
5. Quill.
6. Coote & Co.'s "J."
7. Modern Egyptian Reed Pen.

width in the strokes made by various types of pen, these differences being clearly seen in the enlargement.

It is thus obvious that a measurement of the average width of the pen marks in a given specimen of writing may sometimes be a most important means of differentiation, but it is essential that the precautions given by Osborn should be observed. The measurements should be made by means of a filar micrometer, and the strokes selected for the comparison should in each case be those of average minimum width running in the same direction. A large number of such measurements should be made, and the average taken. The same method is also applicable for determining whether a disputed piece of writing could have been written with a particular pen; but in such cases it is necessary to bear in mind, as has been said before, that one effect of corrosion or mechanical wear upon a pen is to cause it to make strokes of greater width than when it was new.

The Shading of Pen Strokes.—The amount of ink applied to the paper varies in the course of different letters, the darker portions indicating greater pressure at the particular point. This pressure will vary with the elasticity and breadth of the pen nib, and with the position in which the pen is held in relation to the paper and to the direction of the writing.

In the case of writing sloping to the right, and made with the pen pointing towards the shoulder, the pressure is applied at quite different parts of the letter than when the pen is held with its end pointing away from the shoulder. The result is that, in many instances, one gets darker portions of the lines in one case, where one has lighter portions in the other, and *vice versâ*.

Again, writing done with the pen held vertically with regard to the paper differs very materially from that done with the pen approaching more closely to the plane of the paper. As a rule, in the latter case the characters are not only wider, but also more heavily and uniformly shaded.

Old writing done with a quill pen often shows great variations in the lights and shades, this being due to the greater flexibility of quill points.

The places where pressure is applied to the pen may also differ with the individual writer, so that the amount of shading in a particular portion of a letter may sometimes be characteristic. For example, certain writers make a pause at the end of a letter, such as "e," so that there is a greater accumulation of ink at that point, and, consequently, a darker spot, whilst others reduce the pressure at the end of the letter, so that the pen only lightly touches the paper, and in this case the letter will terminate in a thin light-coloured line. Analogous variations may be seen in the way in which the pressure is applied to the paper during the crossing of the letter "t," and these result in differences in intensity of the colour tone, which may be uniform throughout the line, or paler either at the beginning or the end.

BIBLIOGRAPHY.

Dennstedt and Voigtländer.—*Lehrbuch der Gerichtlichen Chemie*, 1906.

Lucas, A.—*Legal Chemistry and Scientific Criminal Investigation*, London 1920.

Lucas, A.—*Forensic Chemistry*, London, 1921.

Mitchell and Hepworth.—*Inks: Their Composition and Manufacture*, London, 1916.

Osborn, A. S.—*Questioned Documents*, Rochester, U.S.A., 1910.

CHAPTER IV.

THE INK ON DOCUMENTS.

INFORMATION of decisive importance may frequently be obtained by the microscopical and chemical examination of the ink in which the words have been recorded upon a document, and such examination should never be omitted.

"Ink" may be defined as the liquid medium by means of which words or characters are recorded upon paper or other fabric in a more or less permanent form. Usually a descriptive adjective is prefixed to the word, depending upon the use to which the ink is to be put, so that we have such terms as "writing ink," "copying ink," "printing ink," "marking ink," and so on, and a knowledge of the evolution and composition of each of these types is essential for the correct interpretation of the results of the examination.

WRITING INKS.

Carbon Inks.—The earliest type of ink used for writing purposes was an ink composed of finely divided lamp-black, or other form of carbon, mixed with water and glue or vegetable gum. Preparations of this kind in solid form are now used by artists in Europe under the name of Chinese or Indian ink, whilst they are still extensively employed as ordinary writing ink in Egypt and other countries in the East.

According to an ancient Chinese document translated into French by Jametel [1] the earliest Chinese ink, dating back to between 2697 and 2897, was a kind of vegetable varnish, and it was not until about the third century B.C. that the solid product made from lampblack and glue was introduced. The illustration on p. 39 of an early Egyptian slab and muller shows that a similar type of ink was used for producing the hieroglyphics upon the papyri of ancient Egypt.

Carbon ink of this type was also found by Sir Humphry Davy upon the fragments of papyri discovered in the ruins of Herculaneum.[2]

The transition in Europe from carbon inks to iron-gall inks appears to have been very gradual, the earliest reference to the latter type being that of the monk Theophilus,[3] who refers to an iron tannin ink in an encyclopædia of Christian art in the eleventh century. This question is discussed at length in my book on inks.[4]

Modern Carbon Inks.—The most complete account of the carbon writing inks used at the present time in Egypt is that given by Lucas in his book on forensic chemistry.[5] He states that best quality of carbon ink contains as its main ingredient soot derived from the limited combustion of oil, resins, or the like. In some cases the pigment in such inks is derived from the carbonisation of wood or similar material at a relatively

[1] *L'Encre de Chine, d'aprés des Documents Chinois,* traduits par M. Jametel, Paris, 1882.

[2] *Trans. Roy. Soc.*, 1821, ii., p. 191.

[3] *Diversarum Artium Schedula,* lib. i., Cap. xl.

[4] *Inks and their Manufacture,* pp. 4-9.

[5] *Forensic Chemistry,* pp. 79 and 82.

low temperature, and may, therefore, conceivably be devoid of free carbon.

Old Arabic documents, dating from A.D. 1617 to A.D. 1871, which were examined by Lucas in the Government archives at Cairo, showed, in some cases, carbon ink which was of a brown tint, and the same thing was observed in old title deeds (A.D. 1839 to 1870). Hence, carbon inks, presumably containing more or less tarry matter and oils, evidently turn brown on keeping, although carbon inks made with pure carbon are notoriously of a permanent black. Old MSS. in the Sultania Library, Cairo, were found to show numerous instances of brown ink. For example, in the case of the ink on papyri of A.D. 719 to 912, the ink was black in some places and brown in others, whilst in several instances a bronze-coloured zone could be seen round the letters.

Further details of the composition of ancient and modern Egyptian carbon inks will be found in Lucas's communication to the Society of Public Analysts.[1]

Examination of Carbon Inks on Documents.—The fact that free carbon is unaffected by the reagents which will bleach or remove iron-gall inks enables the older type of ink to be readily distinguished from modern ink.

If a drop of strong solution of hydrochlorous acid is applied to a portion of a letter, iron tannate will be rapidly bleached, whereas a carbon pigment will be unaffected. In this way the writer was able to prove that a letter supposed to be in the original writing of Nelson was in reality a lithograph.

[1] *Analyst.* 1922, xlvii., 22.

Lucas[1] calls attention to the need of caution in applying this test to modern Egyptian documents written with a carbon ink upon well-sized parchment paper. If a drop of reagent is applied to such writing, and the excess of liquid removed with blotting paper, it will frequently be noticed that a portion of the writing has disappeared. When, however, the blotting paper is examined the particles of carbon will be found adhering to it, having been mechanically washed off the surface of the document. In fact, this behaviour of carbon ink upon modern Egyptian documents is recommended by Lucas as a good test for such ink. It may be mentioned that Pliny[2] refers to the possibility of removing ink from documents by means of a wet sponge.

An alteration of a document in carbon ink by means of a modern iron-gall ink would be readily detected by the use of a reagent, such as hydrochloric acid. Lucas (*loc. cit.*) records several instances of such forgeries. In one case a document written in carbon ink had been altered in two places, the first time with an iron-gall ink, and the second with a logwood ink. In another case alterations had been made with carbon ink in a document written with an iron-gall ink.

In cases within the writer's experience Indian ink has been added to ordinary iron-gall ink to give an appearance of age (*cf.* p. 64).

Sepia.—The pigment secreted by the cuttle fish (*Sepia officinalis*) has long been used as a colour by artists, and may, therefore, occasionally be met with upon documents. Apparently this source of ink was

[1] *Loc. cit.*, p. 82.

[2] *Nat. Hist.*, xxvii., § 52.

known to the ancient Romans, for Cicero, and, later, Persius (A.D. 34-62) alludes to the use of sepia.

This brown pigment is a complex organic substance, from which a definite compound termed *melanin* has been isolated. Unlike Chinese or Indian ink, it does not resist the action of chemical agents. For example, it is soluble in a dilute solution of potassium hydroxide, and is bleached by chlorine or a solution of bleaching powder.

Further particulars of the chemical characteristics of sepia will be found in Mitchell and Hepworth's "Inks."[1]

Sepia also differs from carbon inks in its fastness to light, for the experiments of Russell and Abney[2] have shown that it is a fugitive pigment.

Iron-Gall Inks.—All the evidence available points to the conclusion that iron-gall inks were in general use prior to the seventh century of this era. Astle,[3] who was Keeper of Records in the Tower of London, found that the black ink used by the Anglo-Saxons in documents of the sixth to the tenth centuries was blacker than the ink on documents of the sixteenth and seventeenth centuries, and attributed this to the inks containing carbon. Blagden,[4] however, tested the writing on these documents with potassium ferrocyanide, and found that in every instance iron was present. It is possible, however, that this iron was derived from impurities in the carbonaceous ingredient of the ink.

[1] Pp. 13-20.

[2] *Journ. Soc. Arts.*, 1889, xxxvii., 113.

[3] *Origin of Writing*, 1803, p. 209.

[4] *Trans. Roy. Soc.*, 1787, lxxvii. (ii.), p. 451.

Lucas [1] has obtained some evidence that iron gall inks were used in Egypt as early as the seventh century A.D.

For centuries there was little change in the methods of making writing inks, which were prepared by infusing crushed galls in water and adding copperas (iron sul-

Fig. 26.—Eighteenth Century Iron-gall Ink.

phate) and gum to the infusion, with, in some cases, the addition of salt as a preservative.

The only differences in the resulting inks would, therefore, be that some would contain more iron, and others

[1] *Analyst*, 1922, xlvii., 22.

more tannin or gum, according to the methods of preparation. Hence, although some inks might give a stronger iron reaction than others in writing on paper, the difference would only occasionally be serviceable as a means of distinguishing between them.

Originally inks were rendered dark enough for use by exposing them to the air for a sufficient time for a dark iron tannate to be formed, and it was not until the latter part of the eighteenth century that dyestuffs appear to have been added as a provisional colour, pending the formation of the black pigment upon the paper.

The use of indigo for this purpose and also for increasing the permanency of the writing was first described by Eisler [1] in 1770, and was first used in this country in 1836.[2] In 1856 Leonhardi patented the use of madder extract, mixed with indigo, as a colouring agent, and termed these blue-black inks "alizarine" inks—a name which was retained long after madder had been dropped as an ingredient.

Blue-Black Inks.—These formulæ represented a great advance in the method of making ink, since it then became possible to prevent, to a large extent, the oxidation until the ink was applied to the paper, the presence of the indigo meanwhile giving the necessary colour.

From that time onwards indigo became widely adopted as an ingredient of ink, and is still used to a considerable extent, although it has long been partly replaced by aniline dyes, and especially by aniline blue, which was discovered in 1861.[3]

[1] *Dintefass*, 1770, p. 7. [2] *Mechanics Mag.*, 1836, xxv., p. 229.
[3] W. H. Perkin, *Journ Soc. Arts.*, 1868.

There is a wide variation in the proportions of solid matter and of iron to organic matter in commercial writing fluids, as was shown by analyses of English

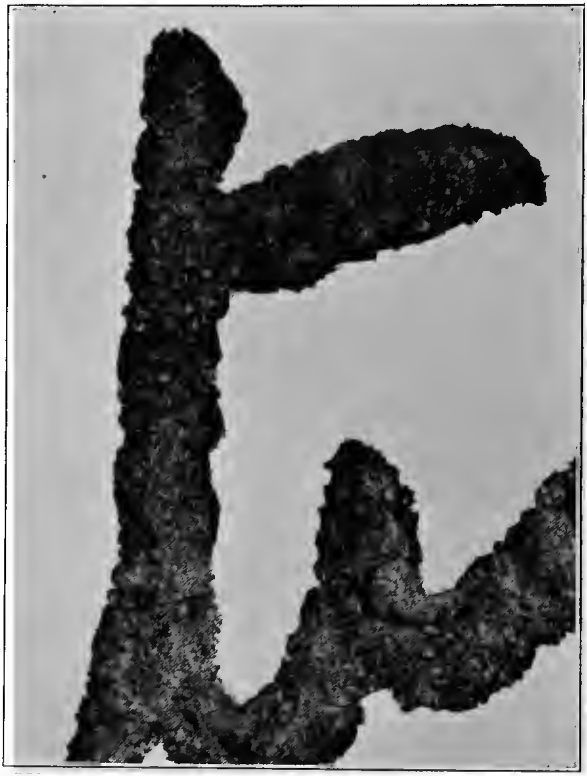


Fig. 27.—Modern Blue-Black Ink.

writing fluids made by the writer.[1] For example, the total amount of solid matter ranged from 1·89 to 7·94

[1] *Analyst*, 1908, xxxiii., 80.

per cent., the ash from 0·42 to 2·52 per cent., and the iron from 0·18 to 1·09 per cent. The dyestuffs in these inks varied in colour from pale greenish-blue to indigo and deep violet, and no two gave identical reactions—at all events when mixed with the iron tannate to form the pigment in writing.

It is mainly owing to the differences in the provisional colour and in the amounts of iron that it is frequently possible to distinguish between different inks in writing, and, in some cases, it is not even necessary to apply chemical tests for the purpose. Thus, in the case of words written with inks having respectively an azure blue and an indigo colour while wet, it is easy to distinguish the colours under the microscope months after the writing has attained its maximum intensity. In comparing the colours of inks for this purpose Osborn's Comparison Microscope (p. 15) will be found invaluable, whilst Lovibond's tintometer glasses (p. 13) will enable a permanent record of the colour to be made.

As an instance of the value of the colorimetric method of differentiating inks, reference may be made to the case of *Rex* v. *Brinkley*, tried in 1907. In that case a will was alleged to be a forgery, one of the reputed witnesses claiming that he had never signed a will at all, but had written his name in a public-house upon a paper, which, he was told, was a petition for an outing. An examination of the disputed document by means of the microscope and tintometer showed that there were three inks upon the document. The body of the will and signature were in one ink, the colour corresponding with that of Stephen's ink, whilst the signatures of the two witnesses were in inks of distinctly different colour.

In particular, the ink in the signature of the impugned witness was of a brilliant blue colour, and corresponded with the colour of the ink (Mordan's) in the bottle in the public-house.

The prisoner did not challenge the correctness of the conclusion that there were three different blue-black inks upon the will, but attempted to give an explanation of the fact. He was found guilty.

Logwood Inks.—The use of logwood was recommended by Lewis [1] in 1764 as a means of improving the colour of iron-gall inks, and by Eisler (*loc. cit.*) in 1770.

Logwood, however, behaves like tannin in giving a permanent coloration with salts of iron and other metals, and is now used as the basis both of black and of violet inks.

Iron logwood inks have a greenish shade which gradually becomes black as the writing dries. Alum logwood inks are deep violet-black in colour, and chrome logwood inks write with a violet colour changing to black. The addition of chromic acid or a chromate to logwood gives eventually a deep black ink, and these compounds form the basis of several cheap writing inks on the market.

It is usually easy to distinguish logwood inks from iron-gall blue-black inks by the colour of the writing under the microscope, and the difference may be confirmed by a chemical test.

Aniline Black Inks.—Inks containing an aniline dye are frequently used for certain purposes, such as stencilling, ticket writing, etc., where great permanence is not an essential. Various allied salts, collectively known as

[1] *Commercium Philisophico-technicum*, London, 1763, p. 377.

"nigrosine," are used in the preparation of such inks, which, when first put upon the market in 1867, were sold as "stylographic inks," owing to the readiness with which they flowed from stylographic pens. Aniline black inks resist the action of various reagents which bleach iron-gall and logwood inks, but can be removed or smudged by the application of water.

Aniline blue-black ink containing nigrosine and other dyes was first introduced in 1867 under the name of "indulin ink."

Differentiation of Inks in Writing.—It was shown by Traill about 1840 that it was possible to distinguish between different inks in writing by the differences in their behaviour on treatment with bleaching and other reagents. The introduction of new types of ink, and the use of various dyestuffs in inks, has greatly increased this possibility, so that a sharp differentiation may thus be effected.

For instance, an ordinary blue-black ink is turned bright blue by hydrochloric acid, turned blue and then bleached by oxalic acid, and bleached by bromine water. A logwood ink becomes bright red on the addition of acid, and is bleached by bromine water, whilst an aniline black ink is slightly smudged by hydrochloric and oxalic acid, and slowly bleached by bromine water.

Numerous reagents might be used for this purpose, but the following will generally be found sufficient for all ordinary inks:—(1) Hydrochloric acid (5 per cent.); (2) oxalic acid (5 per cent. solution); (3) stannous chloride (10 per cent. solution); (4) nascent hydrogen (50 per cent. HCl with zinc); (5) bromine (saturated aqueous solution); (6) sodium hypochlorite

10 per cent. solution); (7) titanous chloride; and (8) potassium ferrocyanide (5 per cent. solution containing 1 per cent. of HCl).

Of these reagents the two first act mainly upon the iron tannate and leave the provisional colouring matter. The third and fourth bleach the iron tannate and reduce the provisional pigment, changing its colour. The fifth and sixth reagents have an oxidising action upon both pigments, and cause more or less superficial bleaching. The titanous chloride acts as a powerful reducing agent towards both pigments, whilst the acidified ferrocyanide solution acts mainly upon the iron liberated from the iron tannate.

The most convenient method of applying them is by means of a pipette, the end of which is drawn out to a capillary point, and the writing should be examined both by reflected and transmitted light, first after five minutes' and then after twelve hours' exposure to the air.

The colorations which appear on the wrong side of the paper are sometimes also very characteristic, especially in cases where there has been superficial bleaching. When using titanous chloride it is advisable to take up the excess of the reagent with blotting paper five minutes after its application to the paper.

By means of these eight reagents the writer has found it possible to distinguish between 25 kinds of commercial writing ink in writing. For matching and recording the colorations produced by the reagents Osborn's comparison microscope (p. 15) will be found very useful, whilst colour standards may then be prepared by the use of various aniline dyes.

The presence of a chromate in an ink may be detected by van Eck's test with α-naphthylamine and tartaric acid, after destruction of the provisional colouring matter by means of an oxidising agent. Benzidine also gives a blue coloration with chromates.

Further details of the methods of testing the ink in writing are given in Mitchell and Hepworth's *Inks* (p. 133, *et seq.*).

Estimation of the Age of Ink in Writing.—It is frequently impossible to express any opinion as to the age of the ink in a given piece of writing, but, in other cases, the facts enable a more or less accurate judgment to be formed.

Anachronisms in the composition of the ink are among the most conclusive of such facts, and the approximate dates at which changes have taken place in the methods of manufacturing ink are, therefore, of importance, as has been pointed in the preceding pages.

Aniline dyes of different kinds were commonly employed in the manufacture of blue-black inks about 1880, and the writer has been able to trace a blue pigment in writing in old ledgers back to about 1885, the writing in the same ledgers prior to that date being in iron-gall inks, which did not show any indication of blue pigment. This point has been found of great importance on several occasions in connection with fraudulent claims for old age pensions. For example, claims have been supported by the production of family Bibles in which entries, alleged to be seventy years old, have been found to be written in ink containing an aniline dye.

In the case of *Rex* v. *Menzies*, tried in 1916, the defendant was accused of having uttered fabricated documents, dating from 1719 to 1772, in support of his claim to a baronetcy. Certain alterations in these documents were alleged to have been written subsequently to 1914, a mixture of blue-black ink and an aniline ink having, it was stated, been used for the purpose. Evidence was given that the ink in this writing did not contain aniline dyes, and that old ink had, therefore, not been imitated in the manner stated. As there was no proof that the alterations in the documents had been made subsequently to 1914, when the defendant had acquired them, he was acquitted.

An earlier case of a similar kind is cited by Wills in his "Circumstantial Evidence," p. 142, in which Alexander Humphreys was tried in Edinburgh, in 1839, for forging several documents in support of his claim to the Earldom of Stirling. On the margin of one of these documents, dated 1639, lines were drawn in red ink, but it was proved officially that the use of such lines was not introduced into the Chancery Office until 1780. Evidence was also given that the ink in some of the attestations was a modern ink made to imitate ink which had become old. It would be instructive to know the grounds on which this last conclusion was based.

Artificial Ageing of Ink.—It is not altogether an easy matter to imitate all the characteristics of old ink in writing. Sometimes an attempt is made to do this by adding sepia or Indian ink to ordinary ink. In one case within the writer's experience a cashier confessed that he had falsified certain entries in a ledger, and, to make them appear older, had written them in a mixture of blue-black and Indian inks. The writing in question, when examined under the microscope, was seen to contain distinct particles of carbon, which could not be bleached either by hydrochloric acid or by hypochlorous acid. These results, therefore, confirmed the statement that Indian ink had been used.

Microscopical Differences in Old and Recent Inks.—For many years after it has been put upon paper an ordinary iron-gall ink of the blue-black type will usually have the appearance of a crystalline structure, which appears to be due to pigment attaching itself to fibres of the paper. Eventually, as the organic matter of the ink decomposes, there is more or less formation of iron oxide or of basic tannates, and the ink not only becomes yellow, but also appears much more amorphous, and, in some cases, shows isolated patches of darker pigment. Good examples of this are frequently to be seen in eighteenth century writing.

As has been pointed out in a previous chapter (p. 42), the division of the points of a steel nib produces heavier impressions at the side of the line, which become still more noticeable when the ink is partially bleached.

In the case of *Rex* v. *Menzies* mentioned above, evidence was given that the additions to a document of 1719 had been made with a steel pen, whereas the rest of the writing had the appearance of having been written with a quill pen (see p. 42).

Colour of Old and New Inks in Writing.—When freshly applied to paper, a mixed solution of iron sulphate and a tannin is pale grey, but it gradually absorbs oxygen from the air, and rapidly darkens as the insoluble tannate forms. In the modern type of blue-black ink, containing both the latent blackish pigment and an added dyestuff to give colour pending the formation of the iron tannate, the colour is first bright blue, and rapidly becomes violet as the other pigment is formed.

The completion of the change—*i.e.*, the production of the maximum intensity of colour—will vary with the conditions. If the ink is applied to the paper in a thin wash, the maximum colour is reached in about a week, and pure iron tannate then begins to fade, turning yellow at the edge.[1]

The changes under these conditions in terms of blue, red, and yellow on Lovibond's colour scale may be illustrated by the records on the opposite page.

If, however, the ink is applied in the ordinary way with a pen, it is left in a deeper layer, and, if then kept in a closed book, its final intensity of colour may not be reached for upwards of a year.

For example, the writer found that specimens of writing with the same blue-black ink, applied with a pen to paper at intervals extending over a year, attained their maximum intensity after periods of eight to ten months. They then showed the following colour on Lovibond's colour scale:—Blue, 3·6; red, 0·4: yellow, 0·4.[2]

Methods of Recording Colour.—It is obvious that if a record is taken of the initial colour of an ink, and the writing is subsequently found to darken rapidly in colour, it is comparatively recent, and, at any rate, will not be more than eighteen months old. In one case, for example, within the writer's experience, an ink, alleged to be upwards of two years old, darkened very materially in a few days, and was thus clearly a forgery.

[1] *Analyst*, 1908, xxxiii., 80. [2] *Analyst*, 1920, xlv., 247.

CHANGES IN THE COLOUR OF INKS ON PAPER.

Days.	1.			2.			3.			4.			5.			7.		
	B.	R.	Y.	B.	R.	Y.	B.	R.	Y.	B.	R.	Y.	B.	R.	Y.	B.	R.	Y.
Iron tannate,	0·9	0·3	..	1·0	0·5	..	1·3	0·6	..	2·0	0·8	0·2	1·8	0·9	0·3	1·6	0·9	0·3
Blue-black ink,	3·0	..	..	3·75	0·5	0·3	4·0	0·7	0·5	4·0	0·7	0·5	3·2	0·7	0·3	3·2	0·6	0·3
Blue-black ink (old),	2·1	..	..	2·8	..	..	3·0	0·5	0·5	3·0	0·5	0·5	3·0	0·5	0·5	3·0	0·6	0·5

Days.	10.			17.			23.			28.			35.			43.		
	B.	R.	Y.	B.	R.	Y.	B.	R.	Y.	B.	R.	Y.	B.	R.	Y.	B.	R.	Y.
Iron tannate,	1·6	0·9	0·3	1·4	1·0	0·3	1·2	0·9	0·3	1·2	0·9	0·3	1·1	0·9	0·4	1·1	0·9	0·4
Blue-black ink,	3·2	0·6	0·3	3·2	0·6	0·3	3·0	0·6	0·2	3·0	0·6	0·2	3·0	0·6	0·2	3·0	0·6	0·2
Blue-black ink (old),	3·0	0·7	0·4	2·85	0·7	0·3	2·85	0·7	0·3	2·85	0·7	0·3	2·85	0·7	0·3	2·85	0·7	0·3

In recording the colour of inks by means of Osborn's comparison microscope and Lovibond's standard glasses (p. 13), it is sometimes necessary to take into consideration the colour of the paper. For example, a faded brown ink of 1868 gave the following readings :—Blue, 0·55 : red, 0·7 : and yellow, 0·1. This was written on blue paper, which gave a reading of 0·50, and evidently contributed to the reading shown by the ink.

Other specimens of old faded inks gave the following readings :—

	Blue.	Red.	Yellow.
Ink of 1718, ...	1·9	1·0	1·9
„ 1792, ...	..	1·2	0·9
„ 1823, .	..	1·1	1·2
„ about 1850, . .	..	0·6	0·6

Tests of specimens of writing done with a freshly made iron-gall ink in the year 1906, before and after the addition of aniline blue, and with and without blotting, and of a specimen of blue-black ink of 1895, were made in 1920—

	Blue	Red.	Yellow.
1. Iron-gall ink without aniline blue, .	2·5	1·4	1·0
2. „ „ „ blotted,	1·1	0·4	0·5
3. „ with aniline blue, . .	4·0	1·2	0·9
4. „ „ „ blotted,	2·0	0·4	0·4
5. Ink in writing of 1895, . . .	2·4	1·4	1·1

For the first four of these specimens the writer is indebted to Mr. A. W. Johnson. The ink No. 5 was originally a well-known bright blue-black ink. At the time of its examination, ten years later, it showed no trace of the original blue dye and had faded to the colour of No. 1, an ink which contained no aniline blue.

For the purpose of demonstrating the colours of ink in Court, a satisfactory but somewhat cumbersome method is to match the ink under the microscope with a broad colour stripe prepared with aniline dyes, and to take a permanent record of this by means of the tintometer.

Influence of Blotting on the Colour of Ink.—As ordinary blue-black ink contains two pigments, one of which is latent, the effect of blotting is to remove variable quantities of these pigments, and the colour of the ink left on the paper will vary with the length of time before blotting.

In the case of *Rex* v. *Cohen*, tried in 1919, a doctor was accused of "doping" a man to keep him out of the army. He asserted that the man was a regular patient, and, as proof thereof, produced his books. There were some seven or eight entries of the name on different dates, and, by a curious coincidence, the ink in all of these was paler than that of the adjacent entries. Mainly on account of this circumstance it was urged by the Crown that these entries were open to grave suspicion of forgery, and Dr. Cohen was sentenced to a fine of £100 and six months' imprisonment. He appealed against this sentence, and subsequent examination of the books by the present writer showed that there was nothing to justify any charge of these entries having been made subsequently to adjacent entries. Apart from the many possibilities affecting writing done at different times, the fact that the entries were blotted at different periods, sometimes at the end of a series, and sometimes after a single entry, was in itself sufficient to account for variations in the colour and intensity of adjacent entries.

This is clearly shown in the series of tintometer readings on p. 67 of the colours of ink washes which were applied to the paper for measured periods and then blotted. A colour chart, based on these readings, was produced in Court at the hearing of the appeal. It proves conclusively that the paleness of the ink in writing is no criterion of the age of the ink, but depends upon the relative proportion of pigments left on the paper prior to oxidation.

Sequence of Strokes as Proof of Prior Writing.—If two pen strokes in ink cross each other while wet, the point of intersection is indicated by a heavier deposit of pigment, but it is rarely possible to ascertain which stroke is uppermost. If, however, the first stroke is dry before the second is applied, the lines are generally quite distinct, and it is usually possible, with the aid of the microscope, to decide which stroke is uppermost or, in other words, more recent.

Osborn [1] has cited some striking examples of the kind in his book, showing that the method may give conlusive evidence of later additions to a document.

A good instance of this is shown in Fig. 28, which plainly shows that the horizontal line is above the slanting upward line.

[1] *Questioned Documents*, pp. 375-393.

INFLUENCE OF DELAY IN BLOTTING ON THE COLOUR OF INK.

Tintometer Readings: Blue, Red, Yellow.	B.	R.	Y.	B.	R.	Y.	B.	R.	Y.	B.	R.	Y.	B.	R	Y.
	5 secs.			10 secs.			15 secs.			30 secs.			90 secs.		
Blue-black ink, faded in bottle, . .	0·3	0·1	..	0·4	0·1	..	0·9	0·1	..	1·0	0·2	0·1	1·5	0·2	0·1
	5 secs.			15 secs.			40 secs.			90 secs.			2 mins.		
Blue-black ink, same manufacturers, .	1·95	..	0·1	3·2	0·3	0·4	3·0	0·3	0·6	3·5	0·6	0·6	3·5	0·9	0·4
	10 secs.			40 secs.			1 min.			2 mins.			3 mins.		
Black ink, German, ...	1·1	1·5	..	1·6	2·0	0·1	1·7	2·1	0·3	1·9	2·6	0·2	2·6	3·0	0·8
	20 secs.			1 min.			90 secs.			2 mins.			3 mins.		
Black ink, English, ...	0·8	1·2	0·2	3·0	2·0	2·0	4·0	3·2	2·7	4·2	3·2	2·7	4·5	3·2	2·7

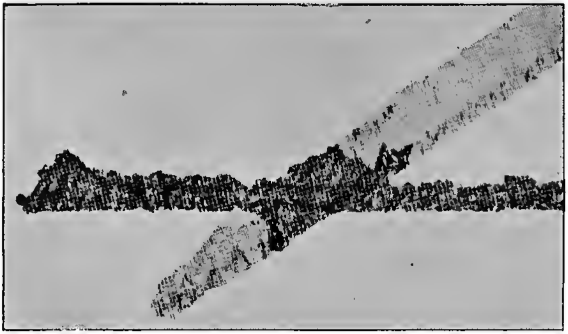


Fig. 28.—Priority of Writing shown by sequence of Strokes.

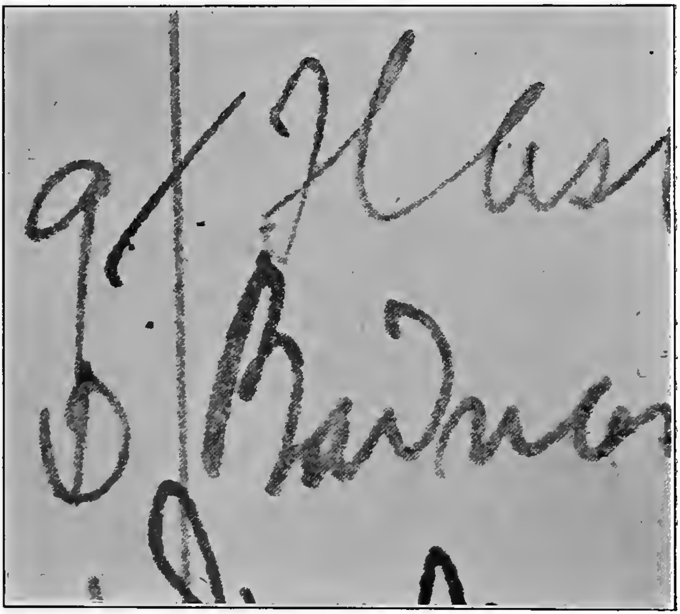


Fig. 29.—Rex *v.* Cohen. Entries in Ledger showing sequence of Strokes.

In the case of *Rex* v. *Cohen*, mentioned above, one of the alleged recent entries touched the entry immediately below it at two points, and in each case the line came below and not above the intersecting line of the subsequent entry. Hence, there could be no doubt that this suspected entry had been written prior to those which immediately succeeded it. A conviction could not be upheld in the face of such facts as these, and the sentence on the defendant was quashed.

Copying Methods.—The use of the ordinary copying process was suggested by Sittl [1] as a means of determining whether the whole of the writing upon a document was contemporaneous. He found that a good copying ink would yield a fair copy on "flimsy" paper for about eight days after writing, whilst, even after four weeks, a faint copy might be expected.

This method was studied by Habermann and Oesterreicher,[2] who found that, under certain conditions, distinct copies could be obtained by the use of a press from the moistened writing in ordinary iron-gall ink for about five months, and, in exceptional cases, up to nineteen months.

Carré [3] had previously suggested the use of dilute hydrochloric acid (1 : 11) in place of water as a copying medium. He found that writing of eight to ten years old would yield a good copy, whereas writing thirty years old gave a faint unreadable copy, and ink of 1787 yielded only traces of pigment to the paper.

Experiments made by the writer have indicated that

[1] *Chem. Zeit.*, 1891, xv., 1833.

[2] *Zeitsch. anal. Chem.*, 1901, xl., 725.

[3] *Comptes rend.*, lxxviii., p. 1213.

results obtained by copying methods should only be accepted with great caution. If, however, there is a pronounced difference between the copying capacity of two parts of the same document, while chemical tests indicate that the inks are of the same type, and the writing is of equal intensity, it is extremely probable that the writing was not done at the same time. More definite conclusions, however, can be drawn if the ink is supposed to be an ancient one, and yet gives a sharp copy.

Chemical Tests for Age.—Iron-gall ink which has recently been applied to the paper reacts rapidly with various reagents, but, after the lapse of a year or so, will only react slowly, and finally, after a period of six to ten years, will remain unaffected for a long time. This difference was first noted by Sonnenschein,[1] and was subsequently recommended by Irvine.[2]

Various reagents have been suggested for the purpose, such as dilute hydrochloric acid, bromine water, hypochlorous acid, oxalic acid, etc.

In the writer's experience a 5 per cent. solution of oxalic acid is one of the most useful reagents, a drop being applied to the selected portion of the writing by means of a capillary pipette. The effect is then followed by means of a lens, and the amount of diffusion, if any, of the blue pigment noted. It is remarkable that in old blue-black ink in writing the aniline blue, if still present, is prevented from diffusing by the insoluble tannate which has been formed. For example, if writing a month or so old is treated with the reagent,

[1] *Lehrbuch der gerichtlichen Chemie*, 1881, p. 364.

[2] *Workshop Receipts*, Spon, 5th Series, 1892, p. 88.

the black pigment will be bleached at once, while the blue pigment will run all over the paper. After the course of three or four years, however, the insoluble iron tannate will only react relatively slowly, and the blue pigment will diffuse very slowly; and after another year or so the reaction will be extremely slow, and all indications of diffusion will stop. These differences are illustrated

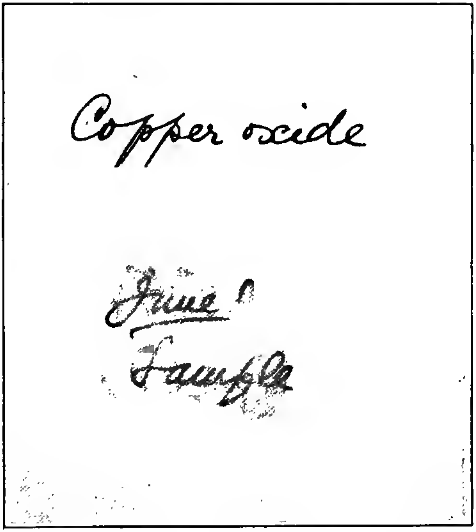


Fig. 30.—Behaviour of old and recent inks with a reagent.

in Fig. 30, which shows the effect of oxalic acid solution upon writing in the same type of ink at an interval of ten years.

In forming any estimate as to the age of ink in writing from the speed of the reaction and the amount of diffusion, it is essential that the dates of the inks should not be too close to each other, that the inks should be of the same type, and that the differences should be very pronounced.

All these conditions were present in the case of *Rex* v. *Pilcher*, which was tried in 1910. Colonel Pilcher was accused of forging his cousin's will, the alleged date of which was 1898. All the inks upon the will, including the signatures of the supposed witnesses, reacted immediately with the various reagents and showed pronounced diffusion of the pigment, the ink running over the paper. On the other hand, a series of parallel tests, which were applied to cheques which had been written by the alleged testatrix, gave the following results :—

(1) 1907. Rapid diffusion.

(2) 1906. Diffusion after a time. Action less rapid.

(3) 1905. July. Heavy writing. Diffusion more rapid than (2), less rapid than (1).

(4) 1905. January. Diffusion less rapid than (3).

(5) 1904. July. Slight diffusion, less rapid than (4).

(6) 1904. January. Heavy writing. Diffusion fairly rapid. More pronounced than (5).

(7) 1903. June. Very slight diffusion.

8) 1903. January. Very heavy writing. Diffusion very slight.

(9) 1903. March. Medium writing. No diffusion.

(10) 1902. June. Heavy writing. No diffusion.

(11) 1902. February. Very heavy writing. Slight indication of diffusion.

(12) 1902. January. Heavy writing. Very slight diffusion.

(13) 1901. June. Heavy writing. No sign of diffusion.

(14) 1901. February. Very heavy writing. No sign of diffusion.

Other tests proved that these cheques had all been signed in the same kind of blue-black ink, and that it was of the same type as the inks upon the will.

Similar results were also obtained in tests applied to a recipe book and various letters of the testatrix, and these supported the conclusion that the alleged will was probably not more than four or five years old, at most. Ultimately Colonel Pilcher confessed that he had uttered the will, knowing it to be a forgery, but that he had no knowledge as to how it had been forged.

In another criminal case (*Rex* v. *Seddon*) a will written in ink showed no indications of having been written at a date later than was stated upon it.

Chemical Changes in the Drying of Ink.—The greater resistance offered by older ink on paper has been accepted as an empirical fact, and it has been left to the present writer to show the chemical reasons underlying the phenomenon.[1]

In the so-called "drying" of ink upon paper there is a slow oxidation of the ferrous tannate first formed. The latter contains about 5·53 per cent. of iron, but eventually changes into another tannate containing about 8·10 per cent. of iron. These two tannates also differ in properties, the oxidised compound being more resinous and very difficult to dissolve in dilute hydrochloric acid. The tannate first formed on the paper is sufficiently soluble in water to allow copies to be taken for a short time, and is readily soluble in dilute acids; but, as the formation of the resinous tannate proceeds,

[1] *Analyst*, 1920, xlv., 247.

the ink becomes increasingly insoluble in dilute hydrochloric acid, and eventually becomes not only relatively insoluble in acid, but also protects the soluble aniline dyestuff present from the action of the reagent. When the oxidation has reached this stage the addition of dilute hydrochloric acid will cause the ink slowly to turn blue, if the blue dye has not yet faded, but there will be little, if any, sign of diffusion or smudging.

COPYING INKS.

As a general rule, copying inks contain most of the constituents of ordinary writing inks, but are made more concentrated, so as to give sufficient pigment to the paper, and they frequently have a small proportion of glycerin or a deliquescent salt added to them to prevent too rapid drying of the ink in the original document. Many of the tests previously described for iron-gall, logwood, and aniline inks are, therefore, applicable to copying inks.

The lines in the copies taken from a document show somewhat blurred edges when examined microscopically, and the margins made by the points of a steel pen will, of course, be lacking in the copy.

In applying tests for the age of ink it is only in exceptional cases that it is possible to draw definite conclusions when a copying ink has been used. The presence of such ink is frequently indicated by the appearance of the pigment.

COLOURED WRITING INKS.

Historical.—There are numerous references in the classics to the use of coloured inks. One of the earliest of such references is by Plutarch, who mentions a red ink which was used for stamping the doors of the *dikasts* in Athens.

A reddish-purple ink was derived from the mollusc *Murex*, the source of the famous Syrian dye, and this is believed to be the ink used by the Byzantine Emperors in their signature to documents.

According to Astle[1] green ink was frequently used in Latin MSS., but was rarely seen in charters. Gold and silver inks were used by both Greek and Roman Emperors at later periods, and are described by Wecker (*De Secretis*, 1582).

Canneparius (*loc. cit.*) gives various formulæ for coloured inks, such as solution of verdigris in vinegar for green ink, etc. The use of indigo and logwood as dyes was forbidden in the reign of Elizabeth, and the Act was not repealed until the reign of Charles II.

Composition of Coloured Inks.—Prior to the discovery of coal-tar colours various pigments were used for coloured inks, of which the following are typical :—

Red Inks.—Cochineal with ammonia ; Brazil wood extract and alum.

Green Inks.—Verdigris and cream of tartar ; copper acetate solution ; a chromic salt ; indigo mixed with picric acid.

Blue Inks.—Prussian blue ; indigo carmine.

Purple Inks.—Logwood extract, copper acetate and alum.

Violet Inks.—Indigo and cochineal.

Yellow Inks.—Decoction of Persian berries ; gamboge in dilute alcohol ; picric acid solution.

Aniline Inks.—Patents for the use of aniline dyes in inks were taken out in 1861 and 1862 (Eng. Pats. 2972 and 2235), whilst the first aniline colour used alone as an ink was Hofmann's violet, discovered in 1863.

[1] *Origin of Writing*, 1803, p. 209.

Bismarck brown dates from 1866, eosine from 1874, and malachite green from 1878. Much of the red ink now sold is a solution of eosine, whilst methyl violet is the basis of many types of violet ink.

It has been shown by Cross and Bevan[1] that all aniline colours are fugitive when exposed to sunlight, and that eosine and methylene blue, in particular, fade very rapidly.

Methods for the examination of typical coloured inks are given in Mitchell and Hepworth's book.[2]

INKS FOR TYPEWRITERS.

Inks are applied to the type of the machine either by means of a travelling ribbon saturated with the liquid, or by bringing the type into contact with a felt pad similarly saturated. In either case the inks are of a similar nature, and may consist of a solution of an aniline dye containing sufficient glycerin or other thickening medium. In some cases the ink has an oily basis, and the dye is incorporated in the form of a lake.

Dyes commonly used as the colouring material include methyl violet and other aniline violets, methylene blue, and nigrosine. These are more or less fugitive (see pp. 76, 137).

Preparations containing carbonaceous pigments, such as lampblack or gas black, are also frequently used, and may be distinguished by the resistance offered by them to the action of chemical agents.

Typewriting inks may also be differentiated by a series of tests analogous to those used for writing inks (p. 125) and the pigments of copying ink pencils (p. 125).

[1] *Journ. Soc. Arts*, 1891, xxxix., 152. [2] *Loc. cit.*, p. 115, *et seq.*

Carbon Papers.—The papers used for taking carbon copies of typewriting consist essentially of unsized paper impregnated with a pigment, such as an aniline dye or lampblack, distributed in a medium, such as a preparation containing carnauba wax, etc. It is frequently possible to differentiate between the pigments in carbon impressions by the use of suitable tests, whilst pencil carbon copies may be readily distinguished from pencil writing by means of the microscope as described on p. 102.

MARKING INKS.

The juices of various plants have long been used as marking inks in different parts of the world, notably that of the Indian marking nut, *Semecarpus anacardium* and the latex of *Rhus toxicodendron*, the poison tree. Of the chemical marking inks the best known are prepared with a basis of silver, the earliest British patent being that of Reade (No. 11,474, 1846). Gold and platinum were also, at one time, used in marking inks. More recently, aniline marking inks, either in one or in two solutions, have largely displaced silver inks. One of the earliest preparations was that of Jacobsen (1867), in which the two constituents of the ink are mixed just before use, and aniline black is formed within the fibres of the fabric. For details of these and other marking inks reference may be made to Mitchell and Hepworth's "Inks," pp. 205-218.

PRINTING INKS.

A primitive method of printing appears to have been used by the Chinese at a date prior to the Christian era. The earliest "block" book in the British Museum bears the date 1470, and, according to the descriptive catalogue, "the long accepted belief that letter printing from the solid block was necessarily prior to that from movable types, and must, therefore, have been introduced about 1440, is now seriously challenged."

The basis of the early printing inks was lampblack or other form of carbon and boiled linseed oil. In modern inks various other ingredients are introduced to increase the speed of drying or modify other characteristics of the ink. Carbon blacks, obtained from natural gas, are now extensively used in place of lampblack, and are characterised by their rich velvet-like tone.

For full details of the composition of printing inks see Mitchell and Hepworth's "Inks and their Manufacture."

In many cases it would not be possible to distinguish between different printing inks on documents, but in others a microscopical and tintometric examination would show pronounced differences.

Again, in the case of certain inks, the oil will be found to have spread into the surrounding paper, making a sort of halo round the letters, whilst in other cases the inks will behave in a different way on treatment with ether or other solvents for oils. An ink recently applied to the paper can be removed more readily than an old ink the oil of which has become completely oxidised.

RESTORATION OF FADED INK.

Although an iron-gall ink which has been properly prepared will, under favourable conditions, retain its colour on paper for centuries, it may speedily fade when exposed to chemical reagents, such as residual traces of chlorine or acid in paper or acid fumes in the air. Again, if too little iron was used in the manufacture, the ink may fade, even under normal conditions, so that eventually the writing may become invisible.

It is, therefore, not infrequently necessary to use scientific methods to restore the ink, or, at any rate, decipher the writing. Chemical methods of restoring the pigment are based upon the fact that the iron constituent of the ink still remains in the paper after the disappearance of the tannin, and that by applying a reagent which will form a coloured iron compound the original writing may be reproduced.

Of the various methods used for this purpose the oldest is to sponge the writing with an infusion of galls, the tannin of which will combine with iron to form a new ink. This method is described by Canneparius in his book on inks (1660).

A better method is that suggested by Blagden in 1787, which consists in treating the writing with a dilute solution of potassium ferrocyanide and very dilute hydrochloric acid, the mixed reagents forming Prussian blue, or an analogous compound, with the residual iron in the paper. It was by the use of this reagent that Blagden was able to prove that the writing on certain vellum manuscripts of the ninth to the fifteenth centuries was in iron-gall and not in carbon inks (see p. 51).

A modification of this method, devised by Lehner, is to immerse the paper for a few seconds in pure 1 per cent. hydrochloric acid, so as to bring the iron into a soluble condition, and then to allow it to dry spontaneously. The writing is next dusted over with powdered potassium ferrocyanide, and covered with a glass plate on which is placed a weight. Finally, after a few hours, the paper is thoroughly dried, and the excess of ferrocyanide removed by means of a soft brush.

A more recent method is to treat the paper for a few seconds with a dilute solution of ammonium hydrosulphide until the writing darkens, and then to sponge off the excess of the reagent as rapidly as possible after the desired effect has been obtained. In this method the residual iron in the writing is converted into ferrous sulphide, which appears as a black deposit on the paper. The new pigment formed is, however, unstable, and writing thus restored will become very faint again on oxidation, so that the method can only be regarded as a temporary expedient.

Lehner [1] has, therefore, devised the following for keeping the restored writing for a longer period. The damaged paper is supported on a framework of threads stretched across a shallow box (about 4 inches deep), while a small dish of ammonium sulphide is placed beneath the paper. The box is closed with a glass cover, and, after a short time, the vapours of the ammonium sulphide act upon the iron in the writing, causing it to become first brown and then black. So long as the document remains in the box the restored writing retains its intensity.

Palimpsests.—The term *palimpsest* (from the Greek words παλιν = again, and πσεστος = rubbed) is applied to old manuscripts the parchment of which had been used previously for a similar purpose. The first writing on the skins was obliterated by means of pumice or

[1] *Die Tinten Fabrikation*, p. 144.

some other abrading material, but this mechanical action was, in some cases, insufficient to obliterate completely characters possibly written three or four centuries earlier. Frequently the iron constituent of the first ink had sunk so deeply into the vellum that the original writing could be restored by the use of reagents similar to those described. In this way valuable classical manuscripts have been deciphered beneath worthless writing of some centuries later.[1]

Morides' Method.—The vellum is first softened by soaking it in distilled water, and is then treated with a 1 per cent. solution of oxalic acid to bring the residual iron into a soluble condition, after which it is immersed in a 1 per cent. solution of gallic acid, and is finally washed with water and pressed between layers of blotting paper. It is essential that an excess of oxalic acid should not be used, since otherwise the writing might be completely obliterated. Another drawback of the method is that occasionally the iron gallate, formed with the later ink, causes the whole of the surface of the parchment to be blackened.

A somewhat less drastic method is that proposed by Lehner, in which the parchment is exposed first to the action of steam and then to acetic acid vapour before applying the gallic acid.

Thiocyanic acid vapour (obtained by adding hydrochloric acid to potassium thiocyanate) may also be used as a reagent for developing the latent writing, but has the drawback that it is liable to tint the whole surface of the parchment.

[1] For example, the "Institutes" of Gains were thus discovered by Niebuhr, in 1816, beneath certain writings of St. Jerome in a MS. in the Cathedral Chapter at Verona.

Photographic Methods.—It is frequently possible to decipher such partially obliterated writing by means of photography, the pale yellow colour of the iron oxide from the faded ink appearing black in a photographic copy.

Pringsheim and Gradewiss [1] have devised an ingenious method of intensifying the appearance of the older writing, while reducing that of the more recent writing. Two coinciding negatives, A and B, are prepared, but of different intensity. On the first the old writing is brought out as strongly as possible, whilst the newer writing is kept as faint as possible. On the second negative the two writings are rendered about equally intense. A glass positive is then prepared from this second negative and is superposed on the first negative, so that the lines coincide. On now examining them by transmitted light the surface of the parchment (strong in the negative and faint in the positive) and the more recent writing (faint in the negative and strong in the positive) will neutralise each other, whilst the older writing (strong in both negative and positive) will be rendered much more pronounced.

WRITING ON CHARRED PAPER.

From time to time charred or partially burned documents are submitted to the chemical expert to decipher the writing upon them.

As a rule, an iron-gall ink leaves a deposit of iron oxide which is still faintly visible upon the surface of the carbonised paper, whilst some printing inks also leave a legible deposit, especially such as contain Prussian blue as a constituent. In other cases, however,

[1] *Muspratt's Handbuch Techn. Chem.*, 1905, viii., p. 1397.

the carbon of the printing ink cannot be distinguished from the charred paper.

The marks left by the graphite of ordinary pencil pigments are usually quite distinct, as is also the case with blue pencil pigments containing Prussian blue. Copying ink pencils generally contain more or less graphite, and, although the methyl violet of the pigment disappears, the graphite will remain as a metallic-looking deposit upon the dull black surface. An instance of this was afforded by the charred portions of the fragments in the case of *Rex* v. *Wood* (Fig. 39, p. 131).

The pigments of pencils composed of a basis of clay with an aniline dye, but without a mineral pigment, will as a rule be undecipherable on charred paper.

As a means of strengthening carbonised paper for examination, Habermann [1] has suggested the following method :—The fragments are painted upon the side which is free from writing with a 10 per cent. solution of ammonium acetate or with the "fixing fluid" (containing magnesium and thorium nitrates) used for strengthening gas mantles. They are then dried and gently ignited, so as to leave a white coherent ash. In the case of writing in pencil there is some risk of burning away graphite if nitrates are used, and aluminium acetate is, therefore, preferable as a strengthening medium, although it yields a less coherent ash.

When a mass of burned papers is to be examined, such as, for example, a bundle of certificates or bank notes, or the leaves of a book, the material should be soaked for some hours in water at a temperature of about 40° C. until the sheets or fragments separate,

[1] *Zeitsch. anal. Chem.*, 1909, xlviii., 729.

and each portion should then be floated on to gummed tracing paper and gently pressed between filter paper, and finally dried at a very low temperature.

In the case of minute fragments each separate portion should be transferred, by means of forceps, to tracing paper and sprayed with a dilute colourless spirit varnish, which will cause it to adhere to the transparent base. For photographing the pale writing on the carbonised groundwork Dennstedt and Voigtländer [1] recommend the use of a colour sensitive plate, with a red filter, a fairly long exposure being given, with oblique lighting.

Reiss [2] recommends the following methods of preparing burned fragments of documents for photography:—(1) The fragments are transferred to a sheet of glass, and flattened with the aid of a steam jet and a fixative agent. (2) A glass plate is supported in a 1 per cent. bath of gelatin at 40° C., so that its surface is only just covered. The burned paper or fragments are then immersed so that they are completely moistened, and, after being arranged, are covered with another glass plate, care being taken to avoid air-bubbles.

The remains of the writing are then photographed in direct sunlight or with an arc light on ordinary plates, which should be sufficiently exposed, but not over exposed, and developed with a slow developer (such as ferrous oxalate) to which potassium bromide is added. Intensified prints may be obtained by the use of special printing paper suitable for weak negatives, such as Rembrandt paper, which is coated with a film of yellow dye.

[1] *Baumert's Lehrbuch der gerichtlichen Chemie*, p. 120.

[2] *La Photographie Judiciaire*, 1903, p. 321.

BIBLIOGRAPHY.

ALLEN, A. H.—*Commercial Organic Analysis*, Article, " Inks."

CANNEPARIUS.—*De Atramentis*, London, 1660.

DENNSTEDT, M., and VOIGTLÄNDER, F.—*Baumert's Lehrbuch der gerichtlichen Chemie*, 1906.

HABERMANN AND ŒSTERREICHER.—*Zeitsch. anal. Chem.*, 1901, xl., p. 725 (age of ink).

HINRICHSEN, F. W.—*Die Untersuchung von Eisengallustinten*, 1909.

HOUGHTON.—*Printer's Everyday Book*, 1856.

IRVINE.—*Workshop Receipts*, Spon, 5th Series, 1892, p. 88 (age of ink).

LEHNER, S.—*Ink Manufacture*, 1902.

LEWIS.—*Philosophico-Technicum*, 1763.

LUCAS, A.—*Legal Chemistry and Scientific Criminal Investigation*, London, 1920.

LUCAS, A.—*Forensic Chemistry*, London, 1921.

LUCAS, A.—The Inks of Ancient and Modern Egypt, *Analyst*, 1922, xlvii., 22.

MITCHELL, C. A.—Differentiation of Inks in Writing, *Analyst*, 1908, xxxiii., 80.

MITCHELL, C. A.—Estimation of the Age of Ink in Writing, *Analyst*, 1920, xlv., 247.

MITCHELL, C. A.—*Lunge's Technical Analysis*, 1914, Article, " Ink."

MITCHELL, C. A., AND HEPWORTH.—*Inks and their Manufacture*, 2nd Edition, London, 1916.

MITCHELL, C. A.—Cantor Lectures, " Inks," *Roy. Soc. Arts*, 1922.

OSBORN, A. S.—*Questioned Documents*, Rochester, U.S.A., 1910.

REISS, R. A.—*La Photographie Judiciaire*, Paris, 1903.

SAVAGE.—*Practical Hints on Decorative Printing*, 1832.

SCHLUTTIG AND NEUMANN.—*Die Eisengallustinten*, 1890.

SEYMOUR, A.—*Modern Printing Inks*, 1910.

SITTL.—(Age of Ink), *Chem. Zeit.*, 1891, xv., p. 1833.

SONNENSCHEIN.—*Lehrbuch der gerichtlichen Chemie*, 1881, p. 364.

UNDERWOOD AND SULLIVAN.—*Printing Inks.*

CHAPTER V.

PENCIL PIGMENTS IN WRITING.

THE problem of distinguishing between the writing done with different kinds of pencils is much more difficult to solve than that of distinguishing between different types of inks. The differences in the composition of blacklead pencils are much less pronounced than in the case of ink, and no material chemical change takes place after the pencil pigment is applied to the paper, comparable with the oxidation of ink to form an insoluble tannate.

Dennstedt and Voigtländer [1] conclude that only in very exceptional cases do the pigments show distinctive microscopical features, and that it is not possible to base any differentiation on the presence of the small amounts of impurities in the graphite and clay. The author,[2] however, has shown that the chemical differences are frequently much more pronounced than is commonly supposed, and that, under favourable conditions, it is possible to distinguish between the pigments on paper.

Early Metal Pencils.—Prior to the discovery of graphite, pencils were composed of metallic lead or alloys of lead, which were cast into a suitable shape and wrapped in paper holders. Pencils of this type were in common use until late in the eighteenth century, and for special

[1] *Baumert's Lehrbuch der gerichtlichen Chemie*, 1906, ii., p. 71.

[2] *Journ. Soc. Chem. Ind.*, 1919, xxxviii., 138 T.

purposes, such as writing on bone tablets, are not entirely obsolete at the present day.

One composition used for pencils of this type was known as Arcet's mixture, and consisted of 5 parts of lead, 2 parts of tin, and 8 parts of bismuth.

Another alloy, termed Rose's mixture, consisted of 1 part of lead, 1 part of tin, and 2 parts of bismuth, to which was sometimes added about $\frac{1}{16}$ part of mercury. Carlier's metal pencils, which were in common use in Germany, consisted of 70 parts of lead, 30 parts of bismuth, and about 8 parts of mercury.

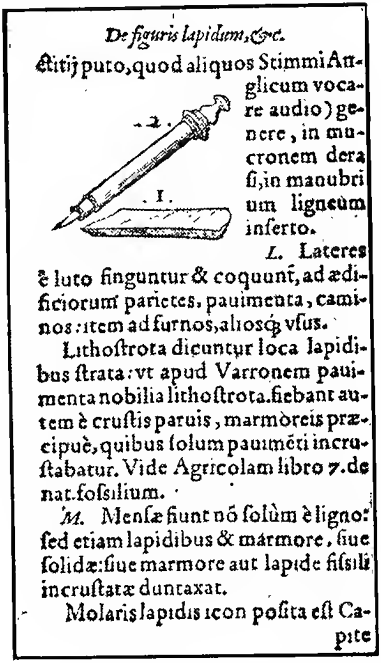
Early Graphite Pencils.—Graphite was discovered at Borrowdale about the year 1560,[1] and from that time until the latter half of the 19th century the black pencils used all over Europe were derived from the Cumberland mines. The graphite was sawn into thin veneers with a wedge-shaped edge, which was glued into a square groove in the wood and then cut off level with the surface, and the upper segment of wood glued down on to this. This method of inserting the wedge into the wood was shown in an exhibit in the Great Exhibition of 1851, and may still be seen in the Geological Museum. Another method was to saw the prepared blocks of graphite ($2\frac{1}{4}$ inches square by 1 inch wide) into strips $\frac{1}{16}$ inch wide, three of which were inserted in the groove of the wood to form a pencil 7 inches long, with a blank end of $\frac{1}{4}$ inch.

The preparation of a wedge of graphite as a stage in the process is shown in the accompanying illustration from Conrad Gesner's book *De Rerum Fossilium Lapidum et Gemmarum Genere*, 1565, Vol. II., p. 105. Incidentally

[1] *Cf.* Note 2, p. 106.

this affords a proof of the antiquity of English blacklead pencils. Fig. 31 (1) shows the graphite cut into a wedge, and 31 (2) a complete pencil. In the text Gesner states that, in his opinion, the material was a sort of artificial lead, which some described as "English antimony."[1]

A fuller description of the properties and uses of


De figuris lapidum, &c.

ctitij puto, quod aliquos Stimmi Anglicum vocare audio) genere, in mucronem deraſi, in manubrium ligneum inſerto.

L. Lateres è luto finguntur & coquunt, ad ædificiorum parietes, pauimenta, caminos: item ad furnos, alioſq; vſus.

Lithoſtrota dicuntur loca lapidibus ſtrata: vt apud Varronem pauimenta nobilia lithoſtrota. fiebant autem è cruſtis paruis, marmoreis præcipuè, quibus ſolum pauimẽti incruſtabatur. Vide Agricolam libro 7. de nat. foſsilium.

M. Menſæ fiunt nõ ſolùm è ligno: ſed etiam lapidibus & marmore, ſiue ſolidæ: ſiue marmore aut lapide fiſsili incruſtatæ duntaxat.

Molaris lapidis icon poſita eſt Capite

Fig. 31.—Gesner's Pencil.

P. 105, vol. ii. *De Rerum Fossilium Lapidum et Gemmarum Genere*, by Conrad Gesner, 1565. (1) Wedge of graphite. (2) Complete pencil.

[1] "Stylus inferus depictus ad scribendum factus est (factetitii puto quod aliquos Stimmi anglicum vocare audio) genere, in mucronem derasi, in manubrium ligneum inserto."

graphite is given by Cæsalpinus,[1] and it is mentioned that it was known as Flemish stone (*lapidem Flandriæ*), owing to its being imported to the Continent by way of Flanders, and that in Germany it was termed "bismuth," and regarded as a mixture fused with antimony for producing characters on paper. It was left to Scheele (1779) to demonstrate the true nature of graphite as a form of carbon mixed with impurities.

The graphite from which the early pencils were made was chosen according to its grade of hardness and blackness for making the different types of pencils. According to Ure (1823) it was sometimes boiled in oil before being sawn up, so as to obtain a softer product. In other pencil works it was heated in luted crucibles to harden the pigment.

About the year 1840 the Borrowdale mines showed signs of becoming exhausted, and various methods of utilising the graphite dust from the works were devised. In one of these, patented by Brockedon (Eng. Pat. 9,977, 1843), the finely sifted graphite was subjected to enormous pressure and to the simultaneous action of a vacuum, so as to obtain compact blocks, which could be sawn up in the same way as the natural product. Specimens of Brockedon's compressed graphite and a solid pencil composed of it are still to be seen in the Geological Museum.

This method was used by several English manufacturers, and, as will be shown presently, the marks made by pencils of compressed graphite can be distinguished microscopically from those made by the original block graphite or the graphite mixtures in

[1] *De Metallicis Libri Tres.* (Paris), 1602, Cap. vii., p. 186.

modern pencils. It was not until about 1869 that the Cumberland graphite was finally exhausted and that composite pencils came into general use.

Modern Composite Pencils.—In 1761 Faber's works were established at Nuremberg, and mixtures of powdered graphite, with sulphur, resins, gums, and other ingredients were used for pencil pigments, but, as may be judged from early specimens of such pencils in South Kensington Museum, they were very inferior to pure graphite pencils, from which also they can be distinguished by the microscopic appearance of the marks on paper.

The modern process of pencil manufacture originated in 1795 with Conté, of Paris, and Hardmuth claimed to have invented the same process in 1798. In the original Conté process fine purified clay and graphite were made into a paste which was forced through small openings in a cylinder, so as to produce circular threads of pigment. These were dried, heated in a covered crucible, and glued into grooves in the wooden holder. The hardness of the pencil depended upon the proportion of clay and the degree of baking.

This process was introduced into this country early in the nineteenth century, and overlapped the older process, which continued to be the principal one. A further development was the incorporation of wax, originally spermaceti, with the pigment, and for this purpose apparatus was devised in which the melted wax was introduced into the material after creation of a partial vacuum. Incorporation of the pigment with wax dates back to about 1840. Various other ingredients, such as lampblack, resins, sulphur, waxes of various kinds have from time to time been incorporated with the graphite pigment, but the nature of these constituents and the methods of mixing the paste and converting it into a solid pigment are jealously guarded as trade secrets.

For the present purpose, however, which is concerned with the behaviour of the pigments on paper, it may be stated that these compositions, mainly of graphite, clay, and wax, all have a similar microscopical appearance on paper, which enables them to be distinguished from the old pencils of pure solid graphite, and, in most cases, from the old compressed graphite.

Composition of Pure Graphite Pencils.—Analyses made in 1825 by Vanuxem[1] of pure Borrowdale graphite showed that the best qualities contained 88·37 per cent. of carbon, 5·10 per cent. of silica, and 3·60 per cent. of oxides of iron and manganese; whilst an impure quality contained only 61·27 per cent. of carbon, 10·1 per cent. of silica, and 20 per cent. of oxides of iron and manganese. Nickel and chromium were also found in Borrowdale graphite, whilst Brandt detected the presence of titanium.

The following analyses were made by the writer[2] of specimens of graphite, for some of which he is indebted to the Curator of the Geological Museum, and to Messrs. Acheson and Mr. Birkbeck :—

[1] *Thomson's Ann. Phil.*, 1826, xi., p. 104.
[2] *Journ. Soc. Chem. Ind.*, 1919, xxxviii., 138 T.

	Carbon.	Ash.	Silicates.	Iron and Alumina.	Microscopical Appearance of Markings.
	Per cent	Per cent	Per cent	Per cent	
1. Borrowdale crude graphite.	52·99	47·01	37·68	10·26	Irregular deposit of pigment. Irregular striations, many following fibres of paper. Few straight lines.
2. Borrowdale graphite used in 1850 for pencil making.	90·33	9·67	7·03	1·08	Irregular disjointed striations, some brilliantly lit up. In lighter strokes irregular striæ following the fibres.
3. Borrowdale graphite.	90·73	19·27	11·44	3·31	Black pigment deposit. Fibres of paper lit up, but few straight striations visible. Type of graphite common in old pencil writing.
4. Ceylon graphite,	92·78	7·22	3·90	2·45	Rich black pigment with brilliant branching striæ. Effect of silvery sheen. Fibres of paper lit up.
5. Greenland graphite.	79·63	20·37	15·30	4·03	Rich black pigment. Numerous irregular striations.
6. Siberian graphite,	77·41	22·55	17·41	0·12	Rich black pigment showing fibrous shimmer. Fine irregular disjointed striations.
7. Acheson artificial graphite.	99·83	0·17	..	Trace	

The first of these specimens was a sample of crude graphite as used for pencil making at about the time the process was abandoned. No. 2 was the specimen of graphite shown in the Great Exhibition of 1851, together with pencils made from it. No. 3 was a typical Cumberland graphite showing the microscopic appearance of the lines in old drawings of the 18th and early 19th centuries. No. 5 was Greenland graphite which was made into pencils for the King of Denmark about 1850. The specimen of Siberian graphite, No. 6 (Geological Museum, Ex. 33) is typical of the graphite used in the manufacture of Faber's pencils. No. 7 was powdered artificial Acheson graphite, and was characterised by its high percentage of carbon and practical absence of iron. Compressed Acheson pure graphite makes marks on paper very similar to those made by Brockedon's compressed graphite (Fig. 33), but they are less brilliant, and are readily distinguished under the microscope. Striations are absent.

Microscopical Examination of Graphites.—It is not only the amount of carbon, but also its physical nature which is of importance, and a microscopical examination of the marks made by the graphite on paper shows why certain specimens of Borrowdale graphite, relatively poor in carbon, give better results than specimens of more crystalline graphite containing more carbon.

In the microscopical examination both vertical and horizontal lines should be examined, the former for the disposal of the pigment, the latter for the structure of the lines. In the horizontal lines the pigment will appear as heaped masses retained by fibres of the paper, in a quantity depending upon the hardness of the pencil and the texture of the paper. This transverse deposition of the pigment can be seen by direct or transmitted light under a relatively low magnification (about 20), but to bring it out clearly it is best to enlarge the photograph to 80 or 100 diameters.

The colour of the pigment on paper may range from a rich black to a pale grey or sepia.

In the case of Borrowdale graphite the vertical lines, when examined with a 1-inch objective with a strong light at right angles to line, will show relatively few brilliant straight striations, and when these occur in the heavier strokes, as for example in Fig. 32, they are disjointed and irregular. The fibres of the paper may be brilliantly lit up by particles of adhering graphite which reflects the light, particularly in those places which have a metallic lustre to the naked eye.

Fig. 32.—Mark made by Borrowdale graphite used for pencil making in 1851. Now in Geological Museum. × 20.

Notwithstanding the high proportion of carbon in the specimen of Acheson graphite (No. 7), the tone was not so rich as that of the finest specimens of Borrowdale graphite.

Other specimens of graphite in the Geological Museum also produced characteristic marks on paper. A pencil made from Canadian graphite (Ex. No. 3,986) gave markings with numerous brilliant striations, irregularly disposed and frequently forming light patches at the edges. Graphite from Huasco, Chili (Ex. No. 7,360), showed a grey pigment, with small brilliant patches and pronounced light striations at the edges. Brockedon's compressed graphite (Ex. No. 57) showed silvery dashes

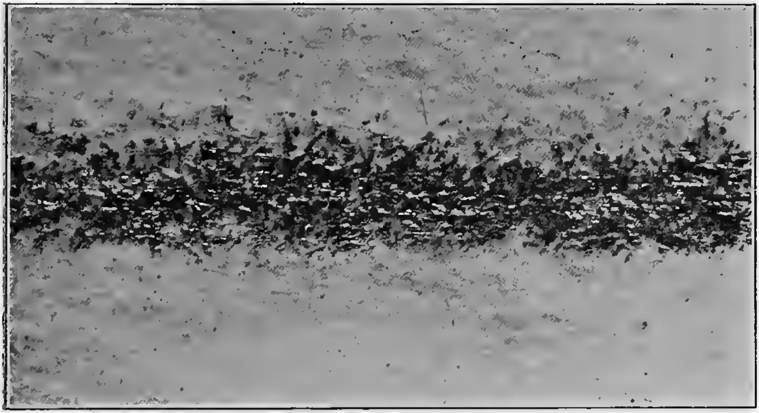


Fig. 33.—Brockedon's Compressed Graphite. × 20.

and lines all over the field, and could readily be distinguished from the natural graphites (see Fig. 33). In some degree the microscopical appearance resembled that produced by some of the very soft modern drawing pencils, such as Koh-i-noor 6 B. Cornish graphite (Ex. No. 30) appeared very similar to Ceylon graphite on paper, but showed fewer irregular striations. Graphite from Upper California (Ex. No. 45) was obviously a very impure specimen. It showed a series of parallel striations in excess of the dark pigment, and the markings might be mistaken for those made by a modern pencil. Such an impure form of graphite, however, would never have been used by the old pencil manufacturers.

Composition of Old Pencil Pigments.—The writer is indebted to Mr. T. H. Court and Mr. Birkbeck for the opportunity of analysing the pigments in specimens of old pencils. The methods of analysis are described in his original paper,[1] and for the present purpose it is sufficient to give the results :—

PIGMENTS IN OLD PENCILS.

Pencil.	Loss at 200-210° Sulphur Cedrol.	Graphite Carbon.	Ash.	Silicates insoluble in HCl.	Iron Oxide and Alumina.	Remarks.
	Per cent	Per cent	Per cent	Per cent	Per cent	
1. In Nairn's box of instruments about 1780.	46·12	41·17	12·71	10·06	2·52	Large amount of sulphur.
2. Do. do.	7·87	44·10	48·03	29·97	large am'nt.	Sulphur present.
3. Do. (Ackermann).	23·32	65·09	11·39	8·71	8·71	do.
4. Pure Cumberland lead (BB).	22·80	51·92	25·28	9·09	12·81	14·91 per cent. of wax, probably cedrol present.
5. Pure Cumberland lead (HB).	2·82	44·21	52·97	6·57	6·57	Small amount of cedrol present.

The specimens Nos. 1, 2, and 3 are interesting as early examples of composition pencils. They were very hard and produced scratchy writing, which, under the

[1] *Journ. Soc. Chem. Ind.*, 1919, xxxviii., 138 T.

microscope, showed irregular striations, and interrupted lines, with deposits of pigment in patches brilliantly lit up. Pencils Nos. 4 and 5 were typical of the graphite pencils in general use about 70 years ago. The marks produced by them were characteristic of those given by the poorer qualities of Cumberland graphite. They showed more interrupted straight striations than are to be found in the lines made by old graphite pencils of better quality.

The specimen No. 4 was remarkable for containing a large amount of a wax-like substance which crystallised in needles, and was evidently an oxidised compound of the nature of cedrol, which had been formed from the cedrene in the cedar oil in the wood and absorbed by the graphite.

Composition of Modern Pencil Pigments.—Full analyses of the pigments in 32 typical modern pencils have been published by the writer.[1] The points of importance for the present purpose are that the pigments consist mainly of variable mixtures of graphite with clay, usually with the addition of wax, and, in some cases, of lampblack or other constituents.

The following table gives typical examples.

The ash in the third column includes both the added clay and the silicious constituent of the original graphite, and it is not possible to distinguish between them. Both, however, have an influence on the microscopical structure of the marks on paper. The colour of the ash ranged from greyish-white through yellow and pink to deep red and brown, according to the proportion and composition of the iron compounds present. These are factors of importance for distinguishing between the marks made by different kinds of pencils.

[1] *Journ. Soc. Chem. Ind., loc. cit.*

PIGMENTS IN MODERN PENCILS.

Pencil.	Carbon.	Loss at 210° Wax Lamp-black.	Ash.	Sili-cates.	Iron Oxide and Alu-mina.	
	Per cent	Per cent	Per cent	Per cent	Per cent	
1. Acheson graphite, No. 515 (between BB and BBB).	64·00	13·23	22·77	21·84	0·66	
2. Conté, No. 5 (about HH).	36·06	8·41	55·53	36·29	5·35	Titanium present.
3. Faber, hard pencil.	57·19	5·26	37·55	32·42	1·99	
4. Hardmuth's Koh-i-noor, 2B.	50·60	15·4	30·00	20·30	1·52	
5. Hardmuth's Koh-i-noor, 6B.	16·56	43·0	40·44	32·16	3·30	
6. Japanese pencil. HB.	43·29	1·85	54·86	52·15	2·57	
7. Rowney's indelible.	29·06	19·94	51·00	43·40	1·45	
8. Spear, carpenter's pencil.	49·12	0·4	50·48	33·97	6·10	Lampblack present.
9. Wolff's indelible.	29·19	28·00	42·81	40·40	2·40	

There was no general agreement between pencils of the same grade made by different manufacturers, thus the HB pencils contained from 30 to 65 per cent. of graphitic carbon, and the HH pencils from 34 to 58 per cent.

On the other hand, the different grades of the same manufacturer frequently show a tendency to contain the same proportion of graphitic carbon, whilst the differences are produced by varying the amounts of the other constituents. For example, in the case of the pigments in two Staedtler pencils (soft and hard) the carbon was 58·74 per cent. in the B pencil and 58·72 per cent. in the H H pencil, while the ash correspondingly increased from 28·42 to 37·28 per cent. The presence of a large amount of lampblack, as in Hardmuth's Koh-i-noor 6 B, increases the depth and colour tone of the pigment on paper, and makes it less lustrous.

MICROSCOPICAL DIFFERENTIATION OF PENCIL PIGMENTS IN WRITING.

The means available for distinguishing between pencil pigments on paper are more restricted than in the case of writing inks or copying ink pencils. The colour, or rather, the depth of tone, is only occasionally of use, for generally it is possible, by varying the pressure or moistening the lead, to make the mark from a hard pencil resemble that from a soft one. In exceptional cases, however, as when one of the pencils contained a large proportion of lampblack, a soft velvet-like black pigment is deposited, which is distinctly different from that produced by a soft graphite pencil.

The Silver Striations.—It was pointed out above that, if the marks made by pure graphite are examined under the microscope in a vertical position, with the light at a right angle, irregular silvery strokes or broken striations may be observed in places, although, in the case of pure old Cumberland graphite, such markings are the exception. These interrupted striæ are most pronounced at points where hard pressure has been applied, so that the pigment deposit appears lustrous to the naked eye.

In the modern pencil pigments in which clay is incorporated with the graphite the fine silicious particles in the mixture are evenly distributed, and appear in the pigment on paper as fine beaded striations, which are parallel and uniform throughout the line. A typical example is shown in Fig. 34, which shows the appearance of the lines produced by Faber's pencil (No. 3 in the list above). It will be noticed that the horizontal line does

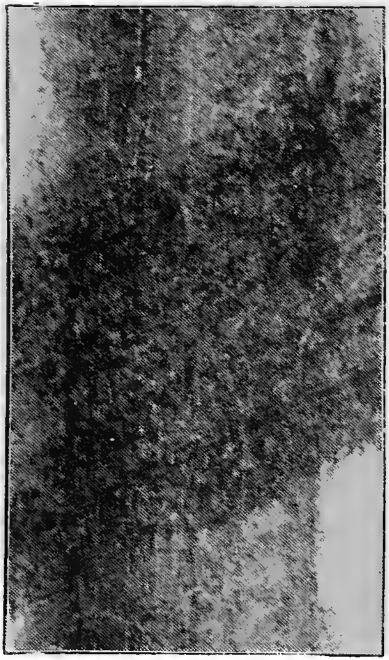


Fig. 34.—Marks made with Faber's pencil. Striations show sequence of lines. × 20.

Fig. 35.—Marks made with Acheson graphite pencil. Striations show sequence of lines. × 20.

not show the striations, which are only visible when the line is placed vertically or nearly so in the field.

The irregular lighting up of patches and interrupted masses of striæ which occur in natural graphite are not, so far as my experience goes, to be found in modern pencil writing. In the case of the latter it is usually possible to follow the bead-like striations from end to end of the line.

Sequence of Strokes.—It is obviously impossible to form any judgment as to the age of pencil writing from its appearance under the microscope, or its behaviour with chemical reagents, as may occasionally be done in the case of writing in ink (see p. 70). But where lines written in pencil have crossed each other the continuity of the silvery striations affords a means of determining which line is uppermost, or, in other words, which of two intersecting lines was written first.

This is clearly shown in Fig. 34, where the striations run uninterrupted from end to end of the vertical lines. In examining crossing strokes it is usually necessary to place each line vertically in the field, but if the angle of intersection is sufficiently acute it is possible to follow the striations simultaneously in each line, and to see where the interruption occurs. Instances of this are shown in Fig. 35, which shows crossed lines made with an Acheson graphite pencil, in which the striations were exceptionally fine. Similar striations are also present in the writing done with copying ink pencil, being produced by the fine particles of clay, incorporated with the pigment (see p. 97), but the irregular distribution of the patches of dyestuff over the line renders it impossible to determine with certainty which line is uppermost, except in cases where the coloured pigment can be removed. The same remark applies to ink writing crossing pencil writing, or to letters stamped with a rubber stamp and intersecting pencil writing. In neither case can the sequence of strokes be determined.

Carbon Copies.—Occasions may arise in which it is of importance to determine whether a particular piece of

Fig. 36.—Carbon copy. Shows absence of striations. × 20.

writing is in the original pencil pigment or in a carbon copy. Since carbon paper has a pigment of lampblack (in a suitable medium) which is merely transferred by pressure to the paper below, no striations should be present in the lines. It will be seen by reference to Fig. 36, which shows the appearance of lines in a carbon copy, that this characteristic affords a certain means of distinguishing between the two kinds of pigments. On the other hand, the absence of striations makes it impossible to determine which of two intersecting lines in a carbon copy is uppermost.

Apart from the striations, the method of depositing the pigment on the paper also causes the lines in a carbon copy to appear different from those in a lead pencil line. In the latter the pigment tends to be deposited in successive ridges as the pencil is drawn across the fibres of the paper, whilst in a carbon copy the pigment is distributed in more irregular masses, and does not form the ridge-like pattern produced by graphite. This difference is best seen under a magnification of about 80 diameters.

Differences in the Striations in Pencil Pigments.—Considerable differences may sometimes be seen in the form of the striations in the lines produced by different kinds of modern pencils, especially those made by different manufacturers. This is due to the fact that different kinds of clay are used in different works, and that in some cases the coarse silicious particles are removed more completely than in others.

For example, in the marks made by the Koh-i-noor pencil 6 B (No. 5 in the table) the striations were plainly visible in the heavy strokes, but were nearly invisible in the lighter strokes, and the irregular lighting up of the striations recalled the appearance of some of the forms of natural graphite.

In the marks made with Wolff's indelible pencil (No. 9) the regular striations were masked by pigment and were faintly visible in the heaviest lines; whereas the marks produced by Rowney's very similar indelible pencil (No. 7) showed fine regular striations which were readily visible even in light strokes.

Again, Faber's pencil (No. 3) produced lines with broad bands of beaded striations (see Fig. 34) which were readily distinguishable from the fine striations in lines made by a Rowney's B pencil.

These variations appear to be due both to the proportion of silicates and to their fineness. The commonest type of pencils, such as the Japanese pencil (No. 6), show abundance of coarse striations. The presence of a large proportion of wax and lampblack, as in Koh-i-noor 6 B (No. 5), also has some influence on the microscopic appearance of the striations.

Differentiation of Old and Modern Pencil Writing.—An examination, made by the writer, of a great number of early specimens of pencil writing has confirmed the conclusions drawn from the differences between the microscopical appearance of natural graphites and that of modern pencil pigments (*supra*).

Through the kindness of the Director of the Science Department, South Kensington Museum, and of Mr. T. H. Court, to whom most of the pencils shown there belong, it has been possible to study the marks made by all the specimens of early blacklead pencils contained in scientific and drawing instruments in the Museum. In no instance were the uniform bead-like striations produced by modern pencils observed, even in the case of the old sulphur composition pencils (*supra*).

As a general rule, lines with the appearance shown in Fig. 37, which represents part of a line in a drawing of 1831, are typical of old pencil writing. Interrupted striations are exceptionally seen in old specimens of pencil markings, although the fibres of the paper are frequently lit up with adherent particles of graphite, as described above.

Fig. 37.—Line in drawing of 1831. Typical of old pencil markings. ×20.

Early References to Pencil Markings.—It is a matter of both antiquarian and scientific interest to determine at what period marks were first made with blacklead pencil on old manuscripts.

Beckmann,[1] in his "History of Inventions," states

[1] *Beiträge zur Geschichte der Erfindungen*, Leipzig, 1780 vol. v., p. 235.

that Le Moine observed blacklead pencil marks in a document of 1387, but doubts whether the observation was trustworthy.

More definite statements are given in a curious book by C. T. Schönemann,[1] dealing with the methods of examining the old documents preserved in the libraries in Germany, and, incidentally, with the occurrence of pencil writing.

It is stated (Vol. I., p. 515) that codices of the eighth to ninth centuries show vertical parallel lines drawn with a stylus; that in the eleventh century documents the first signs of blacklead pencils appear; and that from the twelfth century onwards such marks are of common occurrence. In Vol. II., p. 108) it is asserted that lines in blacklead (*Reisblei*) had been drawn on the *Codex Berengarii Turonensis* of the eleventh and twelfth century, which was in the Wolfenbüttel library. The *Codex Guidonis Aretini de Musica* (eleventh or twelfth century) in the Göttingen library contained vertical and horizontal lines showing traces of blacklead (p. 112), whilst the *Codex Theophili* (twelfth century) in the Wolfenbüttel library showed very fine vertical lines in blacklead.

Now, as graphite was not known until the sixteenth century it is probable that Schönemann mistook markings in ordinary metallic lead for graphite.[2]

[1] *Versuch eines Systems der Diplomatik*, Leipzig, 1818, 2 vols.

[2] Professor Flinders Petrie has kindly given me a portion of a specimen of graphite discovered by him at Ghorub in Egypt. This dates back to between 1,500 and 1,200 B.C., and may have been introduced into Egypt as a specimen. There is no evidence that graphite was ever used as a pigment by the ancient Egyptians. An analysis of this unique specimen by the writer was given in a paper read before the Society of Public Analysts, May, 1922. The sample contained only 39·43 per cent. of carbon, and produced markings typical of a very impure graphite.

The two pigments can be readily distinguished under the microscope. Ordinary lead and some, at all events, of its alloys, produce lines showing a series of irregularly distributed patches uniformly and brilliantly lit up, and each patch is marked with regular vertical striations. The general effect of the pigment distribution is shown in Fig. 38, but the photomicrograph has not brought out the characteristic brilliance and striated structure of the deposit. Type metal (lead, antimony and tin) and

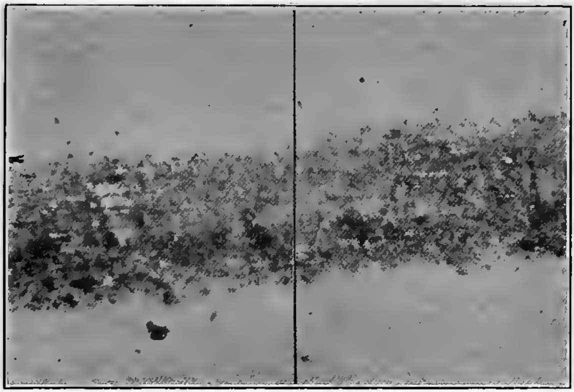


Fig. 38.—Line drawn with Metallic Lead.

solder (lead and tin) produce lines with a very similar appearance, which, except, perhaps, in the size of the deposited particles, can hardly be distinguished from the lines made with pure lead.[1]

Chemical differentiation between metallic lead and graphite is made possible by moistening the surface of the

[1] Pliny (xxxiii., Cap. iii., Sec. 19) mentions that lead and other metals were used for drawing lines on parchment—" argento, aere, plumbo lineæ ducuntur."

paper and exposing it successively to the vapours of hydrogen chloride and hydrogen sulphide, but such a method is not permissible in the case of old documents.

Early Pencil Markings in the British Museum.—It is owing to the kindness of Mr. J. P. Gilson of the MSS. department that the writer has been able to examine specimens of early pencil marks in the writing and drawing in manuscripts in the British Museum.

The earliest example which Mr. Gilson was able to discover was a drawing in Stowe's "Arms of Ancient Nobilitie" (705*a*, 18) of the early seventeenth century. The particles composing the lines of this drawing all reflected the light brilliantly, but were much smaller and lacked the striations which are characteristic of metallic lead. On the other hand, the lines had not the appearance of any form of graphite, the particles being disjointed, and not showing any connecting interrupted striations, as are often to be seen in lines of graphite having a metallic lustre. It is, therefore, probable that this drawing was done with a metallic pencil in which lead did not predominate; possibly the pigment was silver.

A later MS. of Stowe (1691) includes drawings in which the lines show the large isolated particles with the vertical striations characteristic of metallic lead. In another volume of Stowe, however (686), of about the year 1630, the lines in the drawings have the appearance of ordinary graphite.

The pencil markings in two volumes of Sir Thomas Cotton (No. 6,018; about 1630-1640), and Appendix XLV. (1640-1644) have all the characteristics of graphite.

The writing in Lord Hardwick's "Notes on Briefs"

(1718) is undoubtedly in graphite, but a drawing by Vertue (1741) has the appearance of metallic pigment.

A note-book of Hogarth (prior to 1753) contains heavy pencil writing, the pigment of which is a particularly rich graphite. The pencil outline of a drawing on the top of ink in another of Hogarth's note books (47*e*) is also in typical graphite.

The lines in the drawings in a later volume of Stowe (993), about 1747, show fine interrupted striæ, such as are frequently noticeable in the marks made by pure graphite (*supra*).

In Stowe's "Heraldic Collections" (661) of 1763-1764, the pigment in the drawings of the Coats of Arms is also in graphite, and shows the fibres of the paper lit up by adherent particles.

An interesting example of graphite markings is to be seen in a letter from Professor Herrmann (1780) in the Strasbourg MSS. (2,293, fol. 140*b*). This contains a pencil drawing of a fish, in which the pigment has formed branching striations along the lines of the paper fibres.

Various drawings and MSS. of Flaxman (1787-1794) and Blake's MSS. "The Four Zoas of Vala" (1797 to 1803) are all in rich graphite, typical of the best Borrowdale lead, and the same remark applies to the drawings in Buckler's architectural note-books of the years 1799 to 1810. In none of these were there any indications of the use of a composite pencil.

Flaxman was in the habit of making drawings on the backs of the envelopes of letters received by him at Buckingham Street, Fitzroy Square, and a series of these, dating from about 1800 to 1814, is preserved in the British Museum. In every instance the pigment in these drawings is typical of pure graphite, and even interrupted striations are only of exceptional occurrence.

In view of the fact that Conté's process was invented in 1795 in Paris, it is interesting to note, however, that a card sent to Flaxman by the painter Fleury Epinat, of Lyons, between 1805 and 1814, was written with a pencil producing the characteristic fine regular beaded striations of the modern type of pencil. This is the first instance noted of the occurrence of writing in a composition pigment in the MSS. in the Museum.

Of the other manuscripts and drawings of the early nineteenth century mention may be made of the sketch books of J. C. Buckler (son of the Buckler mentioned above) of various years from 1810 to 1836, and of those of his son, C. Buckler (1848-1850), all the lines in which show the characteristics of pure graphite of good quality; whilst a special literary interest attaches to a letter of Byron (about 1809), which is written in a particularly brilliant graphite, and to the pencil corrections made by Keats (about 1820) in his manuscript of "Hyperion," which are also in pure graphite.

The same characteristics of rich pigment deposit, showing only scanty irregular broken striations, may also be seen in a letter of Lord Wellesley written about 1828.

As has been pointed out (p. 90) the manufacture of graphite pencils by the original method was continued until about 1869, but, as the old pencils must have been widely distributed, it is not surprising that the characteristics of pure graphite are frequently to be found in writing, and especially in drawings, for several years after that date. Hence, it is quite in accordance with the development of the industry that the note-book of James Thomson for the year 1869 should be written with a pencil which produced no silvery striations.

Most of the old pencil MSS. in the British Museum have been fixed with a shellac wash, but experiments made by the writer have shown that this does not naturally affect the visibility of the striations, provided a good light be used for the examination.

Early Pencil Markings in the Bodleian Library.—The author is indebted to Bodley's Librarian and to Dr. Craster for facilities for studying early pencil markings in the Bodleian Library. The earliest MS. in that library, known to contain pencil markings, is a discourse on Job (Auct. D. III., 14), and the ruled lines in this are undoubtedly in a metallic pigment. Similar markings appear in Hatton MSS. of the 13th and 14th centuries.

The writing in a curious horn note book of Casaubon (about 1613) is in a metallic pigment, possibly silver.

The first occurrence of graphite writing noted was in an inscription of Anthony Wood in a collection of poems of 1688.[1]

CHEMICAL DIFFERENTIATION OF PENCIL PIGMENTS.

From a consideration of the analyses of natural graphites and of the pigments in modern pencils given above, it will be seen that the most distinctive difference between the pigments in writing will usually be found in the iron present as an impurity in the original graphite or in the clay. Analysis has shown that the iron compounds in the pigments are present in different forms

[1] *Nature*, 1922, cix., 516.

of combination, and vary in their degree of solubility in acids, and on these facts a means of differentiation may often be based.

Sensitiveness of Tests for Iron.—Dennstedt and Voigtländer (*loc. cit.*) assert that the amount of impurities in pencil writing is insufficient for chemical differentiation. To determine the sensitiveness of the various tests for iron the writer made standard solutions of pure ferrous and ferric ammonium sulphates, and of pure metallic iron in hydrochloric acid, and diluted these with water until the point was reached when they no longer gave a visible reaction with the different reagents on paper.

In this way the following results were obtained :—

Iron Salt.	Reagent.	Limit for Amount of Iron Detected.
Ferrous ammonium sulphate.	Potassium ferricyanide.	1 in 18,500
Do. do. do.	Gallic acid.	1 in 66,450
Iron in hydrochloric acid.	Potassium ferrocyanide.	1 in 56,000
Ferric ammonium sulphate + HNO_3.	Do. do.	1 in 37,100
Ferrous ammonium sulphate + HNO_3.	Potassium thiocyanate.	1 in 12,366

Iron in Pencil Pigments.—In the light of these results potassium ferrocyanide appears to be the most suitable reagent, since gallic acid cannot be used in the presence of free mineral acid.

The use of gaseous thiocyanic acid developed from solid potassium thiocyanate was suggested by Dennstedt and Voigtländer [1] for the restoration of faded ink writing (see p. 81), and is also applicable as a reagent for pencil writing. In the gaseous form it appears to be more sensitive than in solution.

The reagents in solution form are best applied to the writing after treatment with a drop of acetic acid, and (in a second test) of strong nitric acid.

Pronounced differences may thus be observed in the behaviour of the writing done with different pencils. For example, marks made with Faber's pencil (No. 3) when treated with nitric acid and potassium ferrocyanide immediately gave an emerald-green drop, rapidly darkening to deep bluish-green. With acetic acid and the reagent a green stain was immediately produced, and, after about three hours, the spot was pale bluish-green, with a narrow dark bluish-green zone.

Hardmuth's Koh-i-noor 6 B (No. 5) gave only a very faint reaction with acetic acid and ferrocyanide, whilst with nitric acid and the reagent the colour was pale green.

Again, a Müller's F pencil, containing 5·06 per cent. of iron in its pigment, gave a much less intense reaction with ferrocyanide than Faber's pencil (No. 3), the pigment in which contained only 1·99 per cent. of iron. Acheson's graphite pencil (No. 1), as was to be anticipated from the analysis (p. 98), gave only the faintest reactions for iron in writing.

Naturally, a blank test must also be applied to the papers on which the writing has been done, and a parallel test should be applied to both the light and heavy strokes of the writing.

[1] *Loc. cit.*, p. 89.

Titanium in Pencil Pigments.—Although titanium has long been known as an occasional constituent of natural graphites it is very exceptional to find it present in pencil pigments in sufficient quantity to give a distinct reaction in the writing. In the case of one of Conté's pencils, however (No. 2, p. 98), the amount of titanium was sufficient to give a bright yellow coloration on treating the writing with hydrochloride acid and hydrogen peroxide.

Chlorides in Pencil Pigments.—A considerable amount of chlorides is sometimes present in pencil pigments, and this fact enables the writing done with them to be distinguished from other pencil writing. The test is best applied as a drop reaction as follows:—A drop of dilute nitric acid is applied to the pencil writing, and silver nitrate is then introduced into the drop, which should retain its globular condition throughout the test. The presence of chlorides is shown by the drop becoming turbid, and the development of the opalescence can be followed with the aid of a magnifying glass.

By this test it was possible to distinguish between the writing done with a pencil of the American Pencil Co. (Dessin No. 2) and that done with Acheson's pencils or Faber's pencils.

Additional Tests.—Soluble sulphates are rarely present in pencil pigments, but a reaction is occasionally obtained. The test is made as a drop reaction with barium chloride and nitric acid in the same way as the chloride test.

In some cases confirmatory evidence may be obtained by a test with dilute nitric acid, which will remove the pigment rapidly from some pencil writing, whilst it has little effect upon others. This difference appears to be due to the wax in some pigments repelling the acids.

Thus, on treating writing done with Faber's pencil (No. 3) with nitric acid the black pigment was removed, leaving fine particles probably of silica attached to the fibres of the paper, which thus resembled a network of strings of glistening beads. In the case of a Staedler B pencil, the reagent only caused a slight clearance of the fibres, whilst the pigment of Koh-i-noor 6 B (No. 5) was not removed by the acid, even with the aid of slight smudging.

Osmic acid is rapidly reduced by the wax, etc., in the pigments of some pencils, but, as a rule, the results of the tests are inconclusive, since the paper itself may also have some reducing action.

Erased Pencil Writing.—As pencil pigments, unlike inks, do not undergo any appreciable chemical alteration on paper, there can be no question of restoring pencil writing by the application of chemical reagents, as may occasionally be done in the case of faded writing in ink (p. 78).

On the other hand, it is sometimes possible to colour the dents left in the paper by the pressure of the pencil, so as to render the original words visible again. Iodine vapour was first proposed for this purpose by Bruylants [1] many years ago, and the principle was subsequently adapted by Hager to the detection of secret writing (see p. 162).

The places where the paper has been rubbed with indiarubber or with bread to remove the writing will also be revealed by the development of a yellow or brown stain following more or less closely the streaks made in the erasure. By applying the iodine vapour to the

[1] *Pharmazeut. Zentralh.*, 1891, p. 228.

back of the paper the absorption will take place through the fibres, and will frequently colour the pencil indentations differentially before the adjoining parts of the upper surface of the paper are stained.

In the case of pencil writing which has been traced and then partially rubbed out and covered with ink, the latter may be bleached with dilute hypochlorous acid (sodium hypochlorite with hydrochloric acid), and any particles of residual carbon from carbon paper, or of graphite from a blacklead pencil, will be left behind, and the indentations made in the tracing may then be rendered more visible by exposure to iodine vapour.

Photography by transmitted light or by sharp oblique illumination from above will frequently reveal much more detail than can be distinguished, even with the binocular microscope. It will show where erasures have been made, and will render writing developed with iodine vapour more obvious.

For photographing yellowish paper Dennstedt and Voigtländer [1] recommend the use of a colour-sensitive plate and yellow screen. The negative should be somewhat over-exposed, and then intensified, and the prints made under yellow glass.

The so-called "Rembrandt" printing paper, which is coated with a film of a soluble yellow dye, has given good results in the writer's hands in the intensification of faint marks on the negative.

Spectroscopic Examination.—The spectroscope affords a means of distinguishing between different kinds of graphites and lead pencils: although for many purposes

[1] *Loc. cit.*, p. 80.

the test is too delicate. In Lunt's[1] researches graphite cores from lead pencils were used to replace the iron terminals of the apparatus and the sparks spectroscopically examined.

Different brands and grades of the pencils of the principal manufacturers were found to vary chiefly in their proportion of alkaline earth metals, whilst there were slighter variations in the intensity of the spectroscopic lines of titanium, vanadium, and chromium.

In the case of natural graphites three specimens from Ceylon showed only traces of iron and calcium. Bavarian graphite contained traces of chromium and vanadium, and South African graphite gave only a faint titanium line.

BIBLIOGRAPHY.

BECKMANN, J.—*Beiträge zur Geschichte der Erfindungen*, Leipzig, 1780, vol. v.

BUCHWALD, A.—*Bleistifte, Farbige Kreiden und Pastelstifte*, Leipzig, 1904.

CAESALPINUS, ANDREA.—*De Metallicis Libri Tres*, Paris, 1602.

DENNSTEDT AND VOITGLÄNDER.—*Baumert's Lehrbuch der Gerichtlichen Chemie*, 1906.

" Der Vollständige Schreibmaterialist."—Leipzig, 1854.

GESNER, CONRAD.—*De Rerum Fossilium Lapidum et Gemmarem Genere*, 1565.

LUNT, J.—*On the Spectra of Graphites and Lead Pencils, Annals Cape Observatory*, 1913, x., part iv.

MITCHELL, C. A.—*Blacklead Pencils and their Pigments in Writing, Journ. Soc. Chem. Ind.*, 1919, xxxviii., 138 T.

MITCHELL, C. A.—*Characteristics of Pigments in Early Pencil Writing. Nature*, 1920, cv., 12.

MITCHELL, C. A.—*Early Pencil Markings in the Bodleian Library. Nature*, 1922, cix., 516.

SCHAUHÄUSSER, V. E.—*Die Nürnberger Bleistiftindustrie*, 1895.

SCHÖNEMANN, C. T. G.—*Versuch eines Systems der Diplomatik*, Leipzig, 1815.

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[1] *Annals Cape Observatory*, 1913, x. *Spectroscopic Researches*, Part IV., " On the Spectra of Graphites and Lead Pencils."

CHAPTER VI.

COPYING-INK PENCILS AND THEIR PIGMENTS IN WRITING.

THE so-called copying-ink pencil is a comparatively modern invention, but is now so extensively used that its pigment is of frequent occurrence on documents of all kinds, and a knowledge of its characteristics is, therefore, of considerable importance in forensic chemistry.

Early Copying-ink Pencils.—One of the earliest applications of aniline dyes was in the preparation of inks which could be used for copying purposes. The essential difference between ordinary writing and copying inks has already been described (p. 74). Unlike iron-gall copying inks, which form an insoluble pigment on oxidation, and so will only yield good copies for a short time after writing, concentrated solutions of aniline dyes will produce writing which does not undergo any natural change on exposure to the air for a relatively long period, and from which, therefore, a copy may be taken at any subsequent period.

Most of the commercial inks of this type contain sugar, glycerin, or deliquescent salts to give consistency, and to prevent their drying up in open bottles, and various compositions, patented for the purpose, have been described by the writer.[1] Methyl violet has long been

[1] *Inks and their Manufacture*, 2nd Ed., 1916, p. 203.

the favourite dye for this purpose, and is given as the main constituent in the earlier formulæ for such inks.

This copying quality of solutions of aniline dyestuffs suggested the incorporation of the pigment with the graphite composition of a blacklead pencil, which would then be capable of producing characters from which one or more copies could be taken on damp paper in a copying press.

The earliest reference to copying-ink pencils appears to be a description of their composition by Viedt[1] in 1875. In his article it is stated that the pigment consists of a mixture of kaolin clay, graphite, and methyl violet, and that gum arabic is not a suitable binding material. A year previously a patent was taken out by Petit (Eng. Pat. 4,090, 1874) for the manufacture of pencils of this type, but it was abandoned before completion.

It is probable that at the present time such pencils are but seldom employed for copying purposes, but are commonly used for producing writing which cannot be erased so readily as the marks of a lead pencil. Hence, they are also frequently termed "indelible pencils," although the description is only relatively correct.

Composition of the Pigments.—Lehner[2] gives the following as the composition of the pigments in four types of copying-ink pencils made by Faber, of Bavaria, No. 1 representing the softest and No. 4 the hardest pencil :—

[1] *Dingler's polyt. Journ.*, 1875, ccxvi., p. 96.

[2] *Ink Manufacture*, Eng. Trans. from 8th German Ed., 1902, p. 125.

	Aniline Dyestuff.	Graphite.	Kaolin Clay.
	Per cent.	Per cent.	Per cent.
No. 1, ...	50·0	37·5	12·5
No. 2, ...	44·2	32·6	23·2
No. 3, ...	30·0	30·0	40·0
No. 4, ...	25·5	24·5	50·0

The methods used by the writer for the analysis of the pigments in these pencils are described in detail elsewhere.[1] In brief they consisted in estimating the moisture by drying the powdered pigment in the water-oven, and then extracting the dyestuff with alcohol. The residue from the extraction was ignited to obtain the ash, whilst the graphitic carbon was taken as the difference. The residue of ash was extracted with acid, and iron, aluminium, etc., were estimated in the acid solution by the usual methods.

In this way the following results were obtained with the pigments typical of those on the market from 1907 to 1918 (see pp. 122 and 123).

From these results it will be seen that the proportion of dyestuff in these pigments ranged from less than 25 per cent. (Nos. 13 and 18) to about 50 per cent. (Nos. 12 and 20).

As part of the ash is derived from impurities in the original graphite it is only possible to make an approximate estimation of the relative proportions of graphite and kaolin clay from these figures. Impure graphite may contain 50 per cent. or less carbon, but the better

[1] *Analyst*, 1917, xlii.

kinds used for pencils usually contain, after purification, not more than 3 or 4 per cent. of impurities (silica, iron oxide, etc.) (see p. 91).

When the amount of ash is less than 5 per cent., as in the case of Nos. 4, 12, 13, 17, 18, 21, and 22, it is probable that the mineral matter was derived solely from the graphite. The ash of No. 14 (8·76 per cent.) consisting largely of ferric oxide was also probably due to the graphite.

The total amounts of mineral matter ranged from 2·79 per cent. in No. 22 to 56·11 per cent. in No. 6. By attributing about 5 per cent. (calculated on the entire pigment) to the graphite and adding this to the loss of ignition, a result approximating to the proportion of impure graphite originally present would be obtained.

These pigments may, therefore, be classified into four main groups—viz., (1) those composed of graphite and dyestuff only; (2) those in which the dyestuff has been incorporated with approximately equal proportions of kaolin and graphite (Nos. 2, 3, 5, and 8); (3) those in which the kaolin is largely in excess; and (4) one instance (No. 15) where the graphite predominates.

The amount of iron oxide left on igniting the pigment ranged from *nil* to 14·54 per cent. in No. 1, in which it constituted about a third of the total ash.

The alumina extracted from the ash with hydrochloric acid ranged from 0·59 per cent. (No. 3) to 19·37 per cent. (No. 19). Where alumina was present in quantity it acted as a mordant, so that about 5 per cent. of the total dye was not extracted by alcohol, and the residue was of a pale mauve colour. Its presence affected the behaviour of the solution tests on paper and probably

No.	Description.	Origin.	Date.	Moisture Loss at 100° C.
				Per cent.
1	American Pencil Co., Duplex blue,	U.S.A.	1911	2·38
2	,, ,, Duplex violet,	U.S.A.	1916	3·96
3	,, ,, "Ink Ean," No. 60,	U.S.A.	1916	7·48
4	,, ,, "Venus," No. 167,	U.S.A.	1916	2·30
5	Eagle Pencil Co., Atlas, No. 823,	London.	1907	4·86
6	,, Copying Eagle Pencil, No. 1,522,	U.S.A.	1911	4·53
7	,, ,, No. 824,	U.S.A.	1911	3·75
8	,, ,, Leads, No. 119,	U.S.A.	1911	3·55
9	Faber, Copying,	Bavaria.	1907	3·72
10	,, ,,	Bavaria.	1911	2·64
11	,, Blue, No. 2,251,	Bavaria.	1907	1·82
12	Hardmuth "Mephisto,"	Austria.	1907	3·56
13	Hessin, Copying Ink, No. 74,	Bavaria.	1911	3·74
14	"Ink and Copying,"	U.S.A.	1911	5·36
15	"Dufferin Copying Pencil,"	Japan.	1918	2·81
16	Kurz,	Bavaria.	1907	3·83
17	Lapis Tinta, No. 180,	..	1911	2·04
18	Rowney,	Britain.	1911	4·53
19	Swan Copying No. 1,039,	Bavaria.	1907	6·33
20	,, No. 1,039,	Bavaria.	1911	2·05
21	Wolff "British Reference,"	Britain	1916	2·72
22	,, "Royal Sovereign,"	Britain.	1916	2·91

Residue Insoluble in Alcohol.	Dyestuff.	Loss on Ignition Graphite.	Ash Kaolin, Etc.	REMARKS.
Per cent.	Per cent.	Per cent.	Per cent.	
76·45	21·30	27·09	47·36	Red ash. Iron oxide = 14·54 per cent.
59·28	36·76	27·36	31·92	White ash. Alumina = 2·19 per cent. Trace of iron.
51·53	40·99	25·48	26·36	Alumina and iron oxide = 0·59 per cent.
60·89	36·81	56·84	4·05	Slight iron reaction.
66·69	28·45	35·78	30·91	Buff coloured ash. Alumina = 1·21 per cent. Trace of iron.
67·77	27·70	11·66	56·11	White ash. Alumina = 2·52 per cent. Trace of iron.
63·95	32·30	13·90	50·05	White ash.
57·14	36·84	22·18	34·96	Putty coloured ash. Iron oxide = 3·00 per cent.
64·48	31·80	11·86	52·86	Alumina and iron oxide = 5·31 per cent.
71·27	26·09	23·50	47·77	Alumina and iron oxide = 13·27 per cent.
58·68	39·50	29·34	29·34	Ash mainly iron oxide.
47·14	49·94	44·14	3·00	Trace of iron.
72·92	23·34	68·12	4·80	Red ash. Good iron reaction.
61·40	33·24	52·64	8·76	Ash mainly iron oxide.
75·03	22·16	61·83	13·20	Yellowish-grey ash. Iron present.
57·59	38·58	40·01	17·58	Trace of iron.
69·36	28·60	64·86	4·50	Buff coloured ash. Good iron reaction.
73·05	22·42	69·17	3·88	Reddish ash. Good iron reaction.
59·83	33·84	7·61	52·22	White ash. Alumina = 19·37 per cent. Trace of iron.
46·43	51·52	5·50	40·93	....
65·48	31·80	62·08	3·40	Red ash, mainly iron oxide.
65·35	32·74	62·56	2·79	,, ,

accounted for the inferior copying properties of some of the pencils (notably Nos. 19 and 20).

The variations in the pigments in pencils of the same type made by the same manufacturers at different periods are shown in Nos. 10 and 11, and in 19 and 20). Making allowances for variations in the grades of graphite it is probable that the two pencils manufactured by Faber were made from the same formula. But there is a pronounced difference in the proportions of dyestuffs in the two Swan pencils made in 1907 and 1911 respectively.

Copying Properties.—Two consecutive copies were taken of writing done with most of these pencils. The best results were obtained with No. 3, "Ink Eau," and No. 12 (Hardmuth's), the worst with No. 16, "Lapis Tinta," and Nos. 19 and 20 (Swan).

The copying properties depend not only on the proportion of dyestuff, but also on the nature of the substratum. For instance, No 20 (Swan), which contained a larger proportion of dyestuff than any of the other pencils, but had a large amount of alumina in its pigment, gave only a very faint copy, whereas No. 14, with a medium proportion of dyestuff, but no alumina, gave a fairly good copy.

The nature of the graphite in the pigment also appears to have an influence on the copying properties. For example, No. 4 (Venus), in which the substratum was mainly graphite gave a relatively poor copy compared with No. 2 (Duplex), which contained about the same amount of dyestuff incorporated with a mixture of graphite and kaolin; whilst one of the best copies was given by No. 12, in which the basis was graphite only.

The behaviour of the characters written with copying-ink pencils on treatment with a drop of water, followed by the application of filter paper, or, in other words, their copying properties in miniature, may thus be used as one of the tests for distinguishing between the pigments of different pencils in writing.

DIFFERENTIATION OF THE PIGMENTS IN WRITING.

Colour Comparisons.—It is possible to distinguish between many of these pigments by the difference in the colour of the writing. For example, pigments which contain a large proportion of kaolin clay or alumina are of a much brighter tint than those in which graphite predominates, and even the intermediate colour may be differentiated to some extent with the aid of the microscope.

For this purpose the comparison microscope devised by Mr. A. S. Osborn (see p. 14) will be found of the greatest use. If desired, a numerical record of the colour may be taken by the use of Lovibond glasses with this instrument.

Solution Tests.—The behaviour of the pigments on treatment with different solvents is frequently characteristic.

If a drop of water be placed on parts of the writing and allowed to remain undisturbed for a few minutes, pronounced differences will be observed with different pigments. In some cases (*e.g.*, Nos. 2, 3, 4, 5, 6, and 12) there is immediate solution of the dyestuff, whilst in others (*e.g.*, Nos. 10, 11, 18, 19, and 20) the drop remains colourless, or practically so, for five minutes or longer.

As was mentioned above, the amount of dyestuff which can be absorbed by applying filter paper to the drop affords a rough indication of the copying capacity of the pigment.

Again, the behaviour with ether may prove distinctive. There is usually a pronounced centrifugal action, but in some cases the dyestuff is diffused over the whole area (Nos. 4, 5, 8, and 13), whilst in others the core is left much paler, or nearly colourless, and a dark zone is formed (Nos. 9, 12, and 16).

A similar test with a drop of acetic acid will sometimes distinguish between two closely similar pigments.

The residue left after removal of the dyestuff by means of acetic acid should be examined under the microscope. When much graphite is present the carbon particles will be seen scattered plentifully over the field, whilst pigments poor in graphite will show only a scanty sprinkling of carbon. The difference between Nos. 15 and 19 in this respect was quite pronounced.

Chemical Tests.—A consideration of the analytical results given in the table on p. 122 indicates that chemical tests of differentiation may be based on the nature and quantity of the dyestuff, on the influence of the graphite, or kaolin clay, on the course of the colour reaction given by the dyestuff, and on the presence of iron, alumina, or mineral impurities in the pigments.

The Dyestuff.—The dyestuff in these pigments may be readily extracted by placing a drop of acetic acid or alcohol on a portion of the writing, and then applying filter paper. To prevent the chance of reduction, the solvent should be allowed to evaporate spontaneously.

The colour reactions of violet dyestuffs thus transferred as spots to filter paper differ somewhat from those given by the same dyestuffs on sized paper, owing to the more rapid diffusion of the reagent in the former case. The influence of any impurities in the dyestuff in the course of the reaction is much more pronounced in the tests on non-absorbent paper.

For example, the reactions on p. 128 were obtained with samples of Methyl Violet and Crystal Violet.

In the tests applied to the filter paper stains, the differences in the colorations given by Methyl Violet Extra III. N and O were mainly in the brilliance of the former, and were hardly sufficiently distinctive to differentiate the two dyestuffs.

The alcoholic extracts from most of the pencils in the table on p. 129 gave very similar colour reactions to these.

In the case of the two blue pencil pigments, however, there was a pronounced difference. The blue Duplex pencil (No. 1) contained a water-soluble blue aniline dyestuff, whilst in Faber's blue pencil (No. 11) the soluble dyestuff, to which it owed its copying properties, was methyl violet, and its blue colour was due to Prussian blue.

In applying these reagents to the pigments of pencils in writing, the course of the colour reactions should be followed under the microscope. Speaking generally, they will resemble the reactions of the residues from the extracts, but will vary in their speed and intensity with the proportion of the dyestuff, whilst the purity of the colour will be affected by the other constituents of the pigment.

REACTIONS OF METHYL VIOLETS ON SIZED PAPER.

Reagent.	Methyl Violet Extra III. N. (B.A.S.F.)	Methyl Violet O. (B.A.S.F.)	Crystal Violet. (B.A.S.F.)
Strong nitric acid.	Bright yellow, with green zone, changing to green.	Yellow to brownish-yellow, changing to dark green, with purple core.	Bright yellow, with thin green zone.
Sulphuric acid, 50 per cent.	Bright yellow, paler in centre.	Yellow to greenish-yellow or brown	Bright yellow.
Stannous chloride.	Grass green, with dark green centre.	Bluish-green.	Pale green, darker zone.
Sodium nitrite with acetic acid.	Blue, with dark blue zone, subsequently bleached.	Blue, with dark blue zone.	Violet-blue centre, light blue and dark blue zones.
Titanous chloride.	Bright yellow, with green zone.	Dark yellow, with faint green zone.	Bright yellow, with thin green zone.
Sodium hypochlorite with acetic acid.	Blue-green centre, dark blue zone before bleaching.	Blue core, white inner zone, dark blue outer zone.	Pale blue, dark blue zone before bleaching.

REACTIONS OF METHYL VIOLET ON FILTER PAPER.

Reagent.	Methyl Violet Extra III. N.	Methyl Violet O.	Crystal Violet.
Nitric acid.	Green, with orange zone.	Dark green, with orange zone.	Bright yellow, then green, with yellow zone.
Sulphuric acid.	Bright yellow.	Dull yellow.	Bright yellow.
Hydrochloric acid.	Bright yellow.	Dull yellow.	Bright yellow, darkening.
Stannous chloride.	Deep green, with darker centre.	Deep green, with plum-coloured centre.	Grass green, with darker centre.
Sodium nitrite with acetic acid.	Blue, with darker zone.	Blue, with darker zone.	Violet-blue, with darker zone.
Titanous chloride.	Yellow, darkening.	Dirty yellow.	Deep yellow.

Reactions of Other Constituents.— Potassium ferrocyanide in 5 per cent. solution is a useful reagent, and is best applied to a spot from which the dyestuff has been extracted by means of acetic acid. In some cases (*e.g.*, No. 22) a pronounced green coloration was obtained immediately, whilst in others there was only the faintest indication of iron after a long period (*e.g.*, No. 5).

Silver nitrate may be used as an additional test, a drop being applied to the writing either before or after treatment with acetic acid. The presence of chloride is indicated by the growing opalescence of the drop, as seen under the microscope. In this way it was possible to distinguish between the pigments in the two violet pencils made by Faber (Nos. 9 and 10). A test for sulphates with nitric acid and barium chloride may be applied in a similar manner (see *Blacklead Pencils*, p. 114).

Illustrative Case.—The case of *Rex* v. *Wood*, tried in 1907, may be cited. Some fragments of partially burned paper, on which were words written in copying-ink pencil, were found in the grate of a room where a woman had been murdered (see Fig. 39).

The resemblance between the writing and that upon a postcard led to the arrest of the man Wood, and in his pocket was found a Swan copying-ink pencil. The question was thus raised whether the pigment of this pencil could have been used in writing the words on the fragments.

The colour of the pigment when applied to paper matched exactly, both in the light and dark portions, the colour of writing on the fragments. It was a very deep purple, quite distinct from the colour of the ordinary

Swan copying-ink pencil (No. 1,039). The colour somewhat resembled that of the pigments by the Eagle Pencil Co., but the solution test with a drop of water sharply differentiated the two pigments. The writing on the fragments and that produced by Wood's pencil

Fig. 39.—*Rex* v. *Wood.*—Charred Fragment with Writing in Copying-ink Pencil.

repelled the water for a long time, and the drops remained practically colourless for five minutes.

Ether produced a fairly uniform stain with very little centrifugal effect, whilst acetic acid acted rapidly, producing zones and extracting much dyestuff. Two good copies could be taken, on the filter paper, of the acetic acid stains, whilst the residue still retained colour. This residue showed a larger proportion of graphite particles than the Swan pencil (No. 1,039), although these were scanty in comparison with results given by pencils rich in graphite.

The ferrocyanide test, applied to the residue from the acetic acid treatment, showed no indications of green coloration at first, and only a slight green tint after drying. In this respect the pigment resembled that of the Swan pencil (No. 1,039).

The colour reactions on the opposite page were given by this pigment in comparison with certain other pigments.

The general course of the reactions of the pigment in Wood's pencil was similar to that of the reactions given by the Swan pencil No. 1,039, but they could be readily distinguished when examined under the microscope.

After having, for some weeks, denied that he had written the words upon the fragments, Wood subsequently admitted that he had done so. He was acquitted of the charge of murder.

Sequence of Lines in Copying-ink Pencil.—The fine silicious particles present in the clay and graphite forming the insoluble basis of copying-ink pencils, produce fine silver striations analogous to those observed in the case of blacklead pencils (p. 99).

The pigment is deposited in heavy masses across the fibres of the paper, and the aniline dye causes them to have almost a metallic shimmer, but, as was pointed out before (*loc. cit.*), the way in which the pigment is deposited interferes with the sequence of the silica

Reagent.	Wood's Pencil and Writing on Fragments.	Swan Pencil, 1,039 (No. 19).	Hessin's Pencil (No. 13).	Faber's Pencil (No. 9).	Eagle Pencil (No. 5).
Nitric acid.	Yellow to deep orange according to amount of pigment. Greenish zone, with tendency to form outer pale zone. Dried with dirty mauve or greenish centre.	Very faint yellow, bleached.	Very pale green slowly darkened to olive green.	Pale green spot, with light yellow zone.	Pale green, darkening to olive green.
Stannous chloride.	Dirty green.	Light dirty green.	Faint lemon yellow.	Faint straw tint.	Faint straw tint.
Sodium nitrite with acetic acid.	Deep bluish-green, leaving pale green core and dark blue narrow zone.	Rapidly bleached, leaving narrow pale blue zone.	Bleached, leaving pale blue zone.	Deep blue zone, nearly colourless core.	Deep blue zone, pale blue core.
Titanous chloride.	Deep yellow, slowly bleached, left pale green core, deep blue zone.	Bright yellow, quickly bleached left very pale green core, with wide blue-green zone.	Yellow, then bleached.	Bright yellow, slowly bleached.	Dirty yellow.
Sodium hypochlorite with acetic acid.	Rapidly bleached. Deep violet-blue zone.	Rapidly bleached. Light violet-blue zone.	Bleached, leaving pale blue zone.	Slowly bleached. Colourless ground.	Rapidly bleached. Colourless area.

striations, so that it is rarely possible to be certain which of the two intersecting lines is uppermost (see Fig. 40).

Exceptionally, however, the silvery striations are rendered much more distinct by removing the violet dye by means of ether and filter paper, and it can then be seen which line was made first.

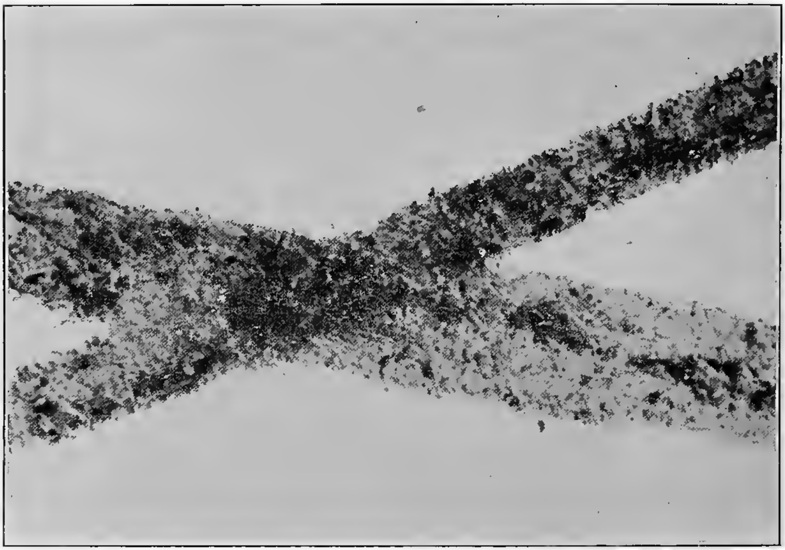

Fig. 40.—Intersecting Lines in Copying-ink Pencil.

Fastness of Copying-ink Pencils.—In the case of *Macbeth* v. *King*, which was tried in 1916, the question of the fastness of copying-ink pencils was raised. The steamship "Membland" was presumably lost at sea early in 1915. Two months later the stave of a wooden bucket was washed ashore near Hornsea, and on this was written in copying-ink pencil the words "'Membland' torpedoed engine room port side. Good-bye dear." (See Fig. 41.)

If this were genuine, it would prove that the vessel had been sunk by war risks, and one set of underwriters would be liable; otherwise it was contended that the ship had fallen a victim to ordinary marine risks.

At the Board of Trade inquiry, in 1915, it had been suggested that a copying-ink pencil would not withstand the action of sea water for two months.

To determine this point the writer made experiments in which words were written with four different kinds of copying-ink pencil upon pieces of oak, which were then placed in a strong solution of salt and water in a glass basin, which was shaken at frequent intervals and exposed for hours at a time to strong sunlight. The writing on these slips remained quite legible after eight weeks, although the words written with Hardmuth's pencil were less smudged than those written with the Eagle or Atlas pencil. The pigment from Faber's pencil was most affected by the treatment. There would, therefore, seem to be little doubt as to the possibility of writing done with a copying-ink pencil remaining relatively unaffected when immersed in sea water for a long period.

In giving his decision, the judge held that conceivably the stave was genuine, but he was not convinced on the point; he decided, however, upon other grounds that the vessel had been lost by war risks (see *Times Law Reports*, 1916, xxxii., p. 581).

The degree of permanence of methyl violet in association with graphite and kaolin has not been ascertained, although it is well known that the dyestuff itself is

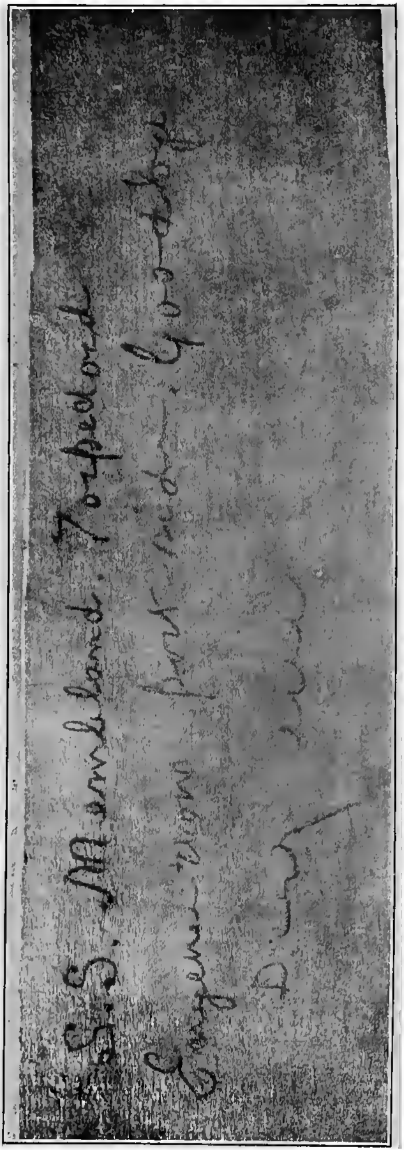

Fig. 41.—Message on Stave from s.s. "Membland,"

fugitive (see p. 76). It is conceivable that under certain conditions the degree of fading might enable an approximate estimate of the age of writing to be formed, as, for example, in the case of two typewritten documents, both typed in the same kind of violet ink and exposed to the same atmospheric influences in the dark. But a large number of experiments would be required to establish any relationship, if such exist, between the age and the fading of the pigment.

In the criminal trial of *Rex* v. *Seddon* the question was raised whether the entries of payments in a note-book over a period of fourteen months had been made on the corresponding dates. The pigment of the copying-ink pencil was of the same character throughout the whole period, but there were no data upon which to base any opinion as to the age of any part of the writing.

BIBLIOGRAPHY.

BUCHWALD, A.—*Bleistifte Farbige Kreiden und Pastelstifte*, Leipzig, 1904.

LEHNER, S.—*Ink Manufacture*, Eng. Trans., London, 1902.

MITCHELL, C. A.—Copying-ink Pencils and their Pigments in Writing, *Analyst*, 1917, xlii.

MITCHELL, C. A.—Article: "Copying-ink Pencils," *Thorpe's Dictionary of Applied Chemistry*, 1921.

CHAPTER VII.

THE EXAMINATION OF HANDWRITING.

UNTIL comparatively recently the examination of handwriting was regarded as something outside the scope of scientific enquiry, and as a subject to which the rules of scientific deduction could not be applied. This widely accepted view must be attributed largely to the methods of handwriting experts in the past. In many instances these men had had no scientific training, and although, by long practice, they had acquired a facility in comparing different handwritings, they not infrequently based their conclusions upon insufficient data, and expressed these conclusions with a degree of certainty which was not warranted by the observed facts.

At one period judges and juries were inclined to accept the dogmatic opinion of the handwriting expert as one which should be received with more or less unquestioning faith, but, at the present day, the attitude has changed, and it is now the work of the handwriting expert to demonstrate by scientific methods the points of resemblance or difference between two specimens of writing, and to explain why he has based a particular conclusion upon these facts. As with all other evidence, conclusions from the characteristics of handwriting can only be drawn with a degree of probability varying with the circumstances, and it is for the Court to decide what degree of probability should be attached to this or any other evidence. At any rate, this expresses the view of the highest Court in the land, for the Lord Chancellor, in his judgment in the recent Wakeford case, remarked :—" This is the manner in which expert evidence on matters of this kind ought to be presented to the Court, who have to make up their minds, with such assistance as can be furnished to them by those who have made a study of these matters, whether a particular writing is to be assigned to a particular person."

Proof of Handwriting.—Formerly the only evidence admitted on the subject of handwriting was the direct testimony of those who had actually seen the writing done, or of those who were well acquainted with the alleged writer, and were, therefore, supposed to have acquired subconsciously an intimate knowledge of the characteristics of his writing. The assumption in the latter case was that they could recognise the writing by what was termed its "general character," by means of a mental process analogous to that which enabled them to identify the writer by his facial characteristics.

Evidence of the results of a comparison of disputed writing with writing admittedly genuine by a witness who had no prior knowledge of the alleged writer was only admissible in the case of ancient documents, or when a document connected with the case was already before the Court.

The earlier law on the subject was thus stated by Blackstone [1] :—" Secondly, though from the reversal of Colonel Sidney's attainder by Act of Parliament in 1689 (*State Trials*, 472) it may be collected that the

[1] Blackstone, *Laws of England*, IV., Cap. 27, p. 358.

mere similitude of handwriting in two papers shown to a jury, without other concurrent testimony, is no evidence that both were written by the same person: yet undoubtedly the testimony of witnesses, well acquainted with the party's hand, that they believe the paper in question to have been written by him is evidence to be left to a jury." (Lord Preston's case, A.D. 1680, *State Trials*, iv., 453; Layer's case, A.D., 1722, *ibid.*, vi., 279; Henzey's case, A.D. 1758, 4 Burr. 644).

Attempts were made to introduce the expert evidence of engravers and examiners of franked letters, but were so consistently rejected that Lord Denman remarked, in the case of *Doe d. Mudd* v. *Suckermore* (5 A. and E. 705), that that chapter might be considered as expunged from the book of evidence; whilst, according to another judge, "in almost all countries, the evidence of persons of skill on the subject is almost totally abandoned."

In a later case a bank inspector attended the Court, heard the admission of a witness that certain signatures were genuine, and subsequently compared the writing with that of a disputed attestation. His evidence was rejected by the judge, and, upon an appeal based upon this rejection, the judges of the Court of Queen's Bench were equally divided in opinion.[1]

It was not until 1854 that a Statute was passed (17 and 18 Vict., c. 125, s. 27) permitting evidence to be given as to the genuineness, or the reverse, of writing, based on a comparison with another specimen of writing, proved to be genuine to the satisfaction of the judge.

For the rules followed in the Courts of the different States in U.S.A. reference may be made to Osborn's

[1] Will's *Circumstantial Evidence*, 1862, 4th Ed., Sec. 3, p. 136.

Questioned Documents and to his communication to the *Illinois Law Review*, 1911, vi. (No. 5), and *Fair Play*, 1912, i. (No. 1). Statutes analogous to the British Statute of 1854 were passed by New York in 1880, and by Pennsylvania in 1896, and, in 1913, a Statute was passed by Congress permitting genuine writings to be admitted for comparison in all Federal Courts.

Evolution of Handwriting.—Handwriting, which may be defined as the expression of thoughts by means of visible symbols, has evolved out of primitive attempts to represent external objects by conventional pictures or hieroglyphics. This view is supported by the fact that insane people not infrequently show a tendency to make use of such pictorial symbols instead of ordinary writing—which, as Lombroso has pointed out, may be the result of an atavistic reversion to the primitive method.

The act of writing is characteristic of the individual, and is, to some extent, frequently an expression of his personality. A man's normal writing is, therefore, often as distinctive as his walk or his mannerisms of speech and gesture. In this connection it is interesting to note that Preyer[1] found that writing produced with the pen held in the mouth, or in the foot, showed the same distinctive characteristics as the writing of the same individual done in the normal manner. The present writer has given an outline of the modern theories of the writing centre in the brain in an article on *The Making of Handwriting*.[2]

Influence of Heredity and Environment.—There is no doubt that heredity plays a part in the particular

[1] *Zur Psychologie des Schreibens*, Hamburg, 1895

[2] *Knowledge*, 1908, v., 255.

form of handwriting, and this is the more noticeable as the type of writing tends to become fixed with the advance of years. Alterations due to temporary influences then largely disappear, and the writing usually becomes more unconscious. Instances of the close resemblances between the writing of parents and children will be found in the article in *Knowledge* cited above, and these could be widely extended by other instances within the writer's experience.

Yet, although writing, if left to develop in a normal manner, will show definite characteristics, these may be considerably modified by such factors as conscious or unconscious imitation. For example, certain mannerisms, at first consciously adopted, tend to become fixed by habit, and ultimately a feature of the normal writing. This is well illustrated by the influence of the writing master in schools, which was responsible for the so-called "Civil Service hand," and the writing which was considered fashionable for ladies in early Victorian days. A good instance of the effect of a business writing school is shown in Fig. 42, which was sent to the author by the late Mr. W. Kinsley, of New York. Each line was written by a different person.

Each age and each country also tends to have its own distinctive forms of writing, and, within certain limits, the general style in use will affect the writing of the individual. As an example of this influence reference may be made to the characteristics of modern Egyptian writing, as cited by Lucas.[1]

Apart from this, the influence of strong emotion, such as grief or terror, or extreme nervousness, may

[1] *Forensic Chemistry*, 1921, p. 98.

influence a particular handwriting, whilst it is well known that old age, incipient insanity, and other diseases of the brain may profoundly affect the writing characteristics. Examples of the influence of these factors will

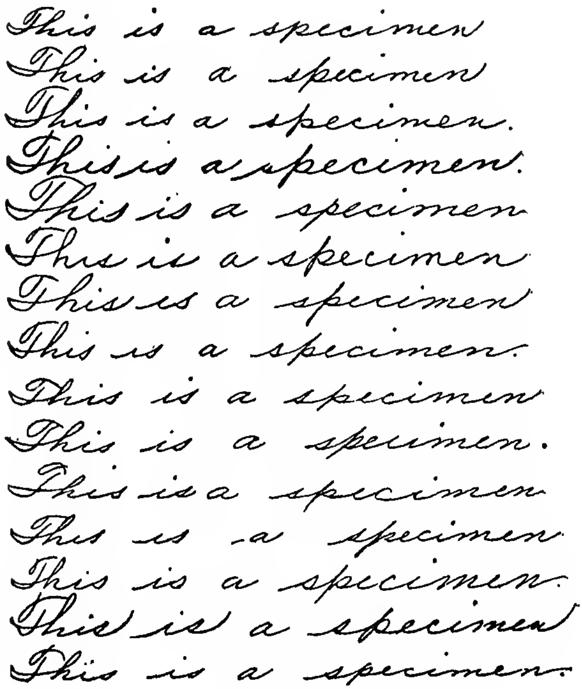

Fig. 42.—Influence of Training on Writing.

be found in the writer's article on *Pathology in Handwriting.*[1]

[1] *Knowledge*, 1909, vi., p. 444. See also Ferrier, *Functions of the Brain*, 1886, p. 448; Scholz, *Die Handschrift*, Bremen, 1885, pp. 19-26; Bastian, *Aphasia and other Speech Defects*, p. 216, *et seq.*

The possibility of all such factors has to be taken into consideration in drawing conclusions from the facts recorded in the examination of writing.

The Writing on Ancient Documents.—The fact that the form of writing varies at different ages sometimes enables a judgment to be formed as to the genuineness of a document, or even to fix its approximate date. For example, a systematic study of Greek papyri has established the forms of Greek script associated with Egyptian documents ranging from B.C. 270 to A.D. 680.[1]

In like manner three main periods have been found in the type of Latin writing in mediæval manuscripts, viz. :—(1) The period of cursive script from the fifth to the eighth century. (2) The period of pure Roman script, in the form of the so-called minuscule, from the eighth and ninth to the close of the twelfth century. And (3) the period of Gothic, neo-Gothic, or monastic writing, from the thirteenth to the sixteenth century.[2]

Typical examples of sixteenth, seventeenth, and eighteenth century writing will be found in the British Museum Catalogue of the MSS. Department, whilst the Netherclifts' book [3] will afford further material for study or reference.

Characteristics of Normal Writing.—In comparing disputed handwriting with a specimen of admitted writing, the questions of pen pressure, fineness of the writing, and microscopic structure of the lines in the letters should be considered and studied by the methods already suggested in previous chapters.

[1] F. E. Kenyon, *The Palæography of Greek Papyri*, 1899.

[2] Schönemann, *Versuch eines Systems der Diplomatik*, Leipzig, 1818.

[3] F. and F. G. Netherclift, *Collection of Autograph Letters*, 1849.

The points to which attention must also be directed, and which, where possible, must also be subjected to microscopical measurement include the following:—(1) Use of uncommon letters, or distinctive parts of letters. (2) The angular slope of the writing. (3) The spacing of words and of individual letters. (4) The position of individual letters relative to the base of the line. (5) The formation of individual letters, and, in particular, the shapes of the curves and the relationship of the angles formed by adjacent parts of letters.

As Osborn[1] has pointed out, there is a blindness to form analogous to colour blindness, and the ability to appreciate and distinguish microscopic differences in form differs greatly with different individuals. Thus, many of the differences in the formation of letters included in the foregoing list of distinctive characteristics would pass altogether unnoticed by a casual observer, whilst others would only be noticed by an eye trained in the observation of microscopic detail.

As an interesting commentary on this inability to discern minute but absolute differences, reference may be made to the case of *Macbeth* v. *King* (see p. 134). The writing upon the wooden stave was recognised by the relations of six members of the lost crew as that of their respective relatives, whereas the mother of the man whose writing corresponded closely in the formation of every letter with the message upon the stave, stated that it was not her son's writing. She had failed to make allowance for the fact that the words were written with a pencil upon wood.

Many interesting remarks on the study of differences

[1] *Form Blindness*, 1913, Rochester, N.Y.

in the formation of letters will be found in the investigation of the handwriting of the anonymous political tract which became famous under the title of *The Letters of Junius*.[1]

The Angular Slope of Writing.—The angles formed by the letters in relation to an imaginary vertical line vary very widely in the writing of different people, and by taking a large number of measurements with the aid of a celluloid protractor the extreme, mean, and average angles for any particular specimen of writing may be obtained. These measurements, however, may vary considerably, even in the case of the same individual, according to the type of pen used, whilst pencil writing is usually much more vertical than pen writing.

Hence, this feature of writing can only be regarded as a rough sorting test, except in cases where there is a sudden and consistent alteration in the angle of particular letters. For example, some people, whilst writing for the most part at a consistent angle of, say, 60° to 65° to the right of the vertical line, form the last letter of their words with a backward slope at an angle of, say, 15° to 20° to the left of the vertical line. Such a characteristic is naturally much more distinctive than even an extreme uniform slope to the right or to the left.

Again, it is a common practice for people who wish to disguise their handwriting to alter its slope. In such cases there is almost always a tendency unconsciously to revert to the normal slope, and wide gradations of angles from left to right of the vertical line may frequently be seen in such writing, whilst the letters,

[1] *The Handwriting of Junius*, by C. Chabot, 1871.

apart from this alteration of slope, may show a close agreement in their mode of formation with those of a suspected specimen of writing.

Connections and Spacings.—The distances left between consecutive words and between the individual letters of words and the strokes of the letters, and the way in which the letters are looped together are among the most distinctive features of writing. To observe these details consistently is by no means an easy task for a forger, and is one of his chief pitfalls; for, as Osborn [1] remarks, "Many of these varied characteristics are as unknown to the average writer as the number of ridges upon the bottom of the feet, and it is such features of writing that most successfully baffle disguise and expose forgery, for the reason that we cannot easily discard that which we do not know we possess nor imitate successfully that which we do not see."

If we compare, for example, the word "lord" as repeatedly written by a number of people, it will be found that the spaces left between—*e.g.*, the base of the "o" and the stroke of the "r," and between the right-hand stroke of the "r" and the left-hand stroke of the "d,"—will approximate in width within certain limits, and that such measurements can be applied to other letters through the writing.

In like manner the lines which connect individual letters take various forms which are more or less constant for the writing of the same individual. Thus, the connecting link may be a fairly straight line or a segment of a circle, or may form a sharp angle with the line serving as the base of the writing. Faulty connections will

[1] *Questioned Documents*, p. 226.

often enable a forgery to be detected, as shown, for example, in Fig. 43.

The Italian or early Victorian handwriting, which is common in all old writing albums, is characterised by the acute angles of the connecting lines, whilst the old-fashioned "copy-book" writing shows rounded connections, which are still more pronounced in some of the types of writing taught in commercial training colleges.

In the "script" writing, which is now the approved

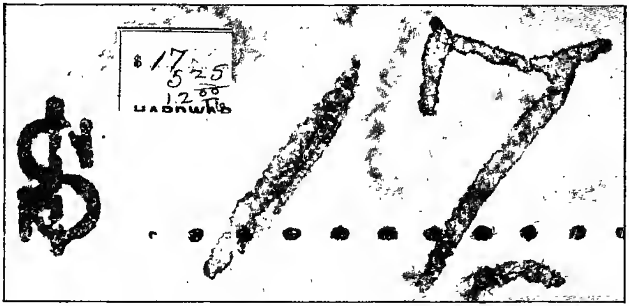

Fig. 43.—Addition to Figure indicated by Faulty Connections

method taught in the L.C.C. schools, each letter is printed separately, and there are no connecting lines.

Unusual Characteristics.—Whilst many people write in a manner conforming more or less closely to a common type, others make some or all of their letters in an unusual manner, and these peculiarities are frequently distinctive of the writing. For example, certain letters may end with a characteristic flourish, or their bases may be carried far below the line, or adaptations of Greek letters may be used. Frequently the cross stroke of the letter "t" is a notable feature, whilst the way in which the "i" is dotted may also be significant. Thus, in the recent case of the *Bishop of Lincoln* v. *Wakeford* the Court laid considerable stress upon the fact that the dots over the "i" in the disputed words were placed well to the right of the "i," and were in the form of an inverted circumflex accent, in which respect they agreed with the admitted writing.[1]

These unusual characteristics are points of importance in recognising disguised handwriting, for, however carefully a writer may try to omit them, there is always a tendency for them to recur, especially in a long letter.

Traced Signatures.—The forgery of signatures by tracing appears to be more prevalent in the United States than in this country, and has been demonstrated on several occasions in the American Courts by means of scientific measurements. Although a traced signature frequently shows an undecided line compared with the original, together with irregularities in the flowing of the ink, this is not always conclusive evidence of its being a forgery. In some notorious cases, however, the model from which the forger traced his copy has been discovered, and the extremely close correspondence between the two signatures has shown that one of them could not be genuine.

An American counsel, in the course of his speech in a trial of this kind, remarked:—"It has been said that if a person meet in a waste place three trees growing in a row, he thinks they were so planted by man. Should he find the distances equal, he is convinced. Such accidental situation of thirty trees would not exceed in

[1] *Cf. The Times*, April 27, 1921.

strangeness a coincidence like the one in this case." In this trial, known as the "Sylvia Ann Howland" case, in which evidence was given as to the coincidence of all the letters in the disputed and genuine signatures, Professor Pierce, of Harvard, stated, in the witness box, that the probability of all the downward strokes in the two writings coinciding would be one chance in nine hundred and thirty-one quintillions.

Fig. 44.—Example of a Traced Signature.

In another celebrated case of the kind, for the details of which the writer is indebted to Mr. A. S. Osborn, a man named Rice died under somewhat suspicious circumstances, leaving an estate worth about five millions of dollars. After the death an attorney named Patrick presented cheques signed with the name of the deceased, and subsequently produced a will according to which he was entitled to the remainder of the estate. This alleged will consisted of four pages, and upon each of these was the signature "W. M. Rice." All four signatures showed the closest correspondence in form, whereas five genuine signatures of Rice, written on the day the will was supposed to have been signed, showed pronounced variations in size, form, and shading. The correspondences in the four disputed signatures were unmistakably shown by means of photography beneath ruled glass squares (p. 7), each portion of every letter occupying the same relative position in its respective square.

They were also demonstrated by the aid of various minute measurements and by photography beneath a superimposed transparent rule, whilst portions of the writing could be cut from one signature and fitted to the corresponding portions of the other signatures.

In traced signatures evidence of retouching may also be obtained in certain cases, whilst, when a pencil is

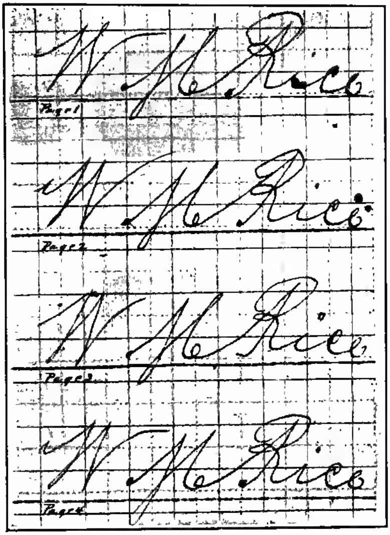

Fig. 45.—Rice-Patrick Case. Traced Signatures.

used for the tracing, remains of the pigment may possibly be found.

The best methods to be used in the examination of documents containing suspected traced signatures are discussed at length by Mr. Osborn,[1] to whom the writer

[1] *Questioned Documents*, pp. 266-301.

wishes to acknowledge his indebtedness for permission to reproduce the examples shown here.

BIBLIOGRAPHY.

ASTLE, T.—*The Origin and Progress of Writing*, London, 1784.

CHABOT, C.—*The Handwriting of Junius, Professionally Investigated*, London, 1871.

CHESNE, J. DE BEAU, AND M. J. BAILDON.—*A Book Containing Divers Sortes of Hands*, London, 1581.

KENYON, F. E.—*The Palæography of Greek Papyri*, Oxford, 1899.

LUCAS, A.—*Legal Chemistry and Scientific Criminal Investigation*, London, 1920.

LUCAS, A.—*Forensic Chemistry*, London, 1921.

MITCHELL, C. A.—*The Examination of Handwriting, Knowledge*, 1908, v., 255.

MITCHELL, C. A.—*Pathology in Handwriting. Ibid.*, 1909, vi., 444.

NETHERCLIFT, T. AND F. G.—*Collection of Autograph Letters*, 1849.

OSBORN, A. E.—*Questioned Documents*, Rochester, U.S.A., 1911.

OSBORN, A. E.—*Proof of Handwriting, Illinois Law Review*, 1911, vi. [5].

OSBORN, A. E.—*Form Blindness*, Rochester, U.S.A., 1913.

PREYER.—*Zur Psychologie des Schreibens*, Hamburg, 1895.

SCHÖNEMANN.—*Versuch eines Systems der Diplomatik*, Leipzig, 1818.

SCHOLZ.—*Die Handschrift*, Bremen, 1885.

CHAPTER VIII.

SECRET WRITING ON DOCUMENTS.

In normal times the use of inks for invisible writing is regarded as more or less of a scientific toy, except in so far as it serves the purpose of fraud or affords the means for illicit communication between prisoners and their friends outside. But things to which little attention is given during periods of peace frequently become of primary importance in war time, and no better instance of this can be found than the immediate use which was made of the methods of secret writing on the outbreak of the Great War. In dealing with this part of the subject it is interesting to note what methods of detecting secret writing were published in German text books prior to the war, and to compare these with the fragments of information published in the English press from time to time as to the use of invisible inks by enemy agents.

Early Invisible Inks.—The use of colourless fluids for secret writing dates back to classical times. Ovid mentions milk as a suitable medium, and Pliny refers to the juice of several plants which could be used for the purpose. The writing done with such " inks " became visible by applying heat to the paper.

The second class of inks, which became visible by the application of a reagent in the form of a gas, were regarded as acting by the force of magnetism, and Brossonius described "magnetic fluids" (aquæ magnetice e longinquo agentes) of this type, which only became visible to the "eyes of affection."

Borel [1] also described these inks, the secret of which had been given to him by Brossonius, but denied that there was anything miraculous about them. They are also mentioned by Robert Boyle (1663), and by Otto Tachen (1669), who agreed with Borel that their action was not due to magnetism. Apparently they consisted of dilute solutions of lead acetate, and the writing done with them was rendered visible by exposing the paper to gaseous hydrogen sulphide. This is described by Lemery (1720).

The term *sympathetic ink* appears to have originated with Le Mort, who applied it to this lead acetate ink, but subsequently the name was extended to all solutions of substances capable of acting as secret inks, and, in particular, to solutions of cobalt salts, the use of which for this purpose was discovered in 1715 by Waiz.

A third group of secret inks includes those which require treatment with another liquid to render the writing visible. Various kinds of this type were described by Baptista Porta (1567), such as, for example, copperas solution, the characters made with which were rendered visible by treatment with a decoction of galls.

Modern Secret Inks.—*Inks Developed by Heat.*—Many of the modern preparations for invisible inks contain a salt of cobalt, as, for example, in Kretschmann's process for secret ink (Eng. Pat. 6,726, 1899), in which paper is prepared with a solution of cobalt chloride, and a solution of common salt is used as the ink. On heating the paper the writing appears in pale green characters.

[1] *Historiarum Centuriæ*, iv., p. 10.

In another patent process (Eng. Pat. 7,367, 1900) Kretschmann treats the paper with a non-hygroscopic salt of cobalt, such as the basic carbonate, and uses as the ink a solution of salt and a substance, such as vinegar, which will convert the salt in the paper into a hygroscopic compound.

Processes such as these are based on the property possessed by certain cobalt salts, such as the chloride, thiocyanate and nitrate, of losing their water of crystallisation when heated to 120° C., and forming a blue anhydrous salt, which gradually absorbs moisture from the air again and regains its faint pink colour, which is nearly invisible on the paper.

Solutions of nickel salts have been used for the same purpose, the writing in this case becoming green on the application of heat.

Lemon juice has long been known as a suitable medium for invisible writing. When applied to the paper it gives characters which, as a rule, will escape notice, but, on heating the paper strongly, those parts with which the fruit acids are in contact char more readily than the rest of the paper, and give a permanent brown writing. Other fruit or vegetable juices may be used for the same purpose, and in Möller's process (Eng. Pat. 21,991, 1897) a mixture of equal parts of alum solution and white garlic juice is used as the ink.

Dilute sulphuric acid can also be used in this way to produce writing which is rendered permanently visible on heating the paper, so as to bring about surface carbonisation. The use of sulphuric acid diluted with 17 parts of water has been claimed by Adams as an invisible ink (Eng. Pat. 3,459, 1896).

The addition of formalin to a fruit juice has the effect of rendering the writing done with the mixture less easily developed by heat, as was proved in the case of *Rex* v. *Kuepferle.*

Inks Developed by Light.—Methods of secret communication have been based on the process of bleaching a photographic print of the writing on bromide paper by means of mercuric chloride, and then rendering the writing visible again by treatment with sodium thiosulphate. Obviously, any soluble silver salt may be used as an invisible ink, the writing remaining invisible so long as it is protected from the light.

Other optical methods depend upon the fluorescence of a solution of a quinine salt under ultra-violet rays, or of other substances when exposed to X rays, radium, etc. A systematic examination of suspected documents must necessarily include such physical methods.

Inks Developed by Mordants.—Any substance which will escape detection when applied to the paper in dilute solution, and yet will form a dark compound on treatment with another reagent, is capable of being used for secret writing.

The use of a solution of copperas (ferrous sulphate) with tannin as the reagent has already been mentioned. Other reactions may be produced on paper by the use of the following groups of substances :—

Black or Brown.—Gallic acid with an iron salt; pyrogallol with an alkali; lead salts with a sulphide; mercuric chloride with stannous chloride; and cobalt chloride with an oxidising agent.

Blue.—Starch with iodine; cobalt nitrate with oxalic acid; ferrous sulphate with potassium ferrocyanide, or *vice versâ*.

Yellow.—Basic lead acetate with hydriodic acid; antimony chloride with tannin.

Green.—Potassium arsenate with stannous chloride.

Purple.—Gold chloride with stannous chloride.

Gold.—Sodium aurochloride with 10 per cent. oxalic acid solution, followed by heating with a hot iron.

This list, which is confined to substances which have long been known as sympathetic inks, might be extended so as to include a large number of organic compounds which will be familiar to every chemist, but the principle involved is the same—viz., formation of a coloured compound from a practically invisible substance.

Information officially given to the press shows that this method of secret writing was in use during the war. For example, it has been stated that a material saturated with potassium ferrocyanide was used by a German agent as a source of invisible ink, which was obtained at will by the addition of water to a portion of the material. On the addition of an iron salt to the writing, Prussian blue, or a similar compound, would be formed.

Saliva and other Secretions as Ink.—In many respects saliva is an ideal fluid for invisible writing, as it is always available, and, unlike chemical preparations such as ferrocyanide, it can be used without attracting much notice. Its use for this purpose was known to German chemists long before the war, as is shown by the reference to the subject in Dennstedt and Voigtländer's *Lehrbuch der Gerichtlichen Chemie*, 1907, p. 122, but it does not appear to have been described in any English text book.

Writing done with saliva may be developed with ordinary writing ink, preferably diluted with a large volume of water. It has been pointed out on a previous page (p. 61) that the darkening of ink is due to the formation of an insoluble black tannate, under the influence of the oxygen of the atmosphere. In the presence of saliva this darkening process is accelerated, possibly through the action of an oxidising enzyme, so that, if the paper is brushed over with dilute ink, the portions written in saliva will appear in dark characters long before the ink on the other part of the paper darkens. If the surface of the paper has been scratched, there will also be a selective absorption of ink at that point, but experiments made by the writer show that the main change is a chemical process; for the black compound formed when ink by itself darkens on exposure to the air differs in composition from that formed when it darkens in the presence of saliva.[1]

[1] The insoluble tannate formed when ordinary ink dries on paper is probably the same compound which is produced by exposing unoxidised ink to the air until it forms an insoluble deposit. These deposits, after being dried at 100° C., have been found by the writer to contain from 5·6 to 6·1 per cent. of iron, which corresponds with Wittstein's tannate, containing 5·88 per cent. of iron. On accelerating the oxidation by adding hydrogen peroxide to the ink, the deposits formed contained from 21·5 to 24 per cent. of iron (corresponding with Ruoss's basic tannate, $C_{14}H_7O_9(FeO)_2$, which contains 24·42 per cent. of iron).

A deposit formed by shaking the ink with a few drops of pine oil contained 8·15 per cent. of iron, corresponding with Pelouze's tannate (containing 8·00 per cent. of iron), whilst saliva threw down a dense black precipitate in 24 hours, containing 7·98 per cent. of iron, or practically the same as in the case of the pine oil precipitate. The ink used in the experiments was a freshly prepared, nearly colourless mixture of ferrous sulphate and tannin solutions, so that any question of the acceleration in the darkening of the ink by saliva or essential oil being a physical rather than mainly a chemical process must be eliminated.

For a description of the various tannates mentioned, see Mitchell and Hepworth's *Inks*, 2nd Ed., pp. 65-70.

According to an account in the *Times* of the work done in the Censorship Laboratory during the war, saliva was used as a secret ink by German agents, and ink was used for its detection on paper.

Apart from its promoting the oxidation of ink on paper, saliva contains constituents which act as a mordant for dyestuffs, so that when a solution of a dye, such as methylene blue, is applied to writing in saliva, and the paper subsequently washed, there is a differential staining, and the colour is fixed in a darker tint on those parts where the characters were made.

Other physiological fluids, such as milk serum, dilute urine, blood serum, etc., behave in a similar manner, and even ordinary tap water, by reason of the salts which it contains, acts, when dried on paper, as a mordant for dyestuffs.

The colourless juices of many plants can be used for the same purpose, and, in particular, the terpene constituents of essential oils have a pronounced action in accelerating the oxidation of ink. Hence, secret writing done with certain perfumes, containing, for instance, oil of lemon, can be developed with ink for a considerable time afterwards.

Saliva and other physiological secretions contain organic substances which char more readily than the cellulose of the paper, so that, in many cases, it is possible to develop the characters by applying strong heat to the surface of the paper.[1]

In the case of paper which contains starch the diastase in the saliva will convert this starch into sugar, so that, on applying a dilute solution of iodine, the paper will

[1] Dennstedt and Voigtländer (*loc. cit.*).

be coloured blue, except in the place where the saliva has acted, with the result that the writing will appear white on a blue ground.

Vanishing Inks.—A special type of ink may be classified under this heading. It has been mentioned that cobalt salts have long been known to give writing which appears on the paper when moderately heated, and disappears on cooling.

Another old preparation, known as *Widemann's Ink*, was composed of 1 part of linseed oil and 20 parts of ammonia solution, in 100 parts of water. In other words, it was a solution of a partially saponified linseed oil. The writing done with this liquid was rendered visible by moistening the paper, and disappeared again on drying.

But the vanishing inks most favoured by racecourse sharpers are those which do not appear again. An ink sometimes used for this purpose is a weak solution of starch coloured blue with a little iodine. Starch iodide is unstable, and characters written with it soon fade away, but the writing could be re-developed by treatment with iodine.

Fugitive dyes, such as quinoline blue, which soon fade away when exposed to sunlight, have also been used for this purpose.

A police court case, which attracted considerable attention at the time, exposed this form of fraud. A betting paper giving the names of various horses was written in two kinds of ink, one of which faded away, whilst the other appeared under the influence of light. In this instance the appearing ink consisted of an ammoniacal solution of silver nitrate.

Himly (Eng. Pat. 730, 1887) prepared a vanishing ink by mixing a solution of platinum magnesium cyanide with a medium, such as gum or gelatin. When exposed to moist air the writing becomes visible in pink characters, which disappear on heating the paper to remove the moisture. In another process, patented by Bachem (Eng. Pat. 8,976, 1899), two substances are used, such as cobalt chloride and magnesium platinocyanide, in two layers, one of which becomes visible on heating, while the other simultaneously disappears.

Use of Secret Inks as a Safeguard on Documents.—Secret inks have been used from time to time as a means of detecting the writer of anonymous letters. This method proved successful in a case in which certain individuals had been subjected to persecution by a series of anonymous letters. Stamps marked with secret ink were sold only to suspected persons, and when these were subsequently found on further anonymous communications it was not difficult to discover the culprit.

To detect tampering with closed envelopes by means of steam, Kretschmann (Eng. Pat. 6,727, 1899) devised a process of making certain marks on the paper with a solution of resorcinol and *p*-toluidine, which, when heated, changes from pale red or yellow and becomes permanently black or brown. In another process, devised by Kromer (Eng. Pat. 2,389, 1877), the two constituents (*e.g.*, tannin and iron) of a sympathetic ink are kept separate in a dry condition by the adhesive gum on the envelope. Should the envelope then be steamed open, the two substances come into contact in the presence of moisture, and form an ink which leaves a permanent stain upon the paper.

Examination of Documents for Secret Writing.—Bearing in mind the fact that the character of the paper may have a considerable influence in preventing secret writing from being quite invisible, it is advisable to examine the paper under a binocular microscope, with powerful oblique illumination (see p. 9).

The marks made by a pen on highly sized paper may thus sometimes be clearly seen, whereas those made with the same pen on a paper with a relatively rough surface might escape detection.

As an additional optical test, Dennstedt and Voigtländer[1] recommend that a photograph should be made of the document, with oblique illumination, on a colour-sensitive plate.

The application of moderate heat would detect the presence of many of the substances mentioned in the foregoing pages, but, in the case of other preparations, would cause volatilisation and remove all traces of the writing from the paper.

The Iodine Test.—The use of iodine vapour as a general reagent for the detection of secret writing was described by Hager, whose methods are quoted by Guareschi.[2] On holding the paper with invisible writing over a basin in which iodine is heated the marks will, in the majority of cases, be rendered visible by absorption of iodine. This absorption appears to be, to a large extent, a physical process due to the sizing being penetrated by the pen, and thus increasing the absorptive capacity of those parts as compared with the rest of the surface.

The iodine test has the advantage that it can be

[1] *Loc. cit.*, p. 125.

[2] *Gli Inchiostri da Scrivere*, 1915, p. 139.

applied without injuring the document, which, when exposed to the air, gradually regains its original appearance.

But iodine, although valuable as a general test, is not infallible, for there are substances, notably certain physiological fluids, which, when used for this purpose, give writing which reacts with ink, but not with iodine.

The Ink Test.—This will detect scratches in the paper, writing with physiological fluids, writing done with salt water, and many of the special secret inks. It is best to use the ink in a dilute form (Dennstedt and Voigtländer [1] recommend a dilution of 1 in 20 as the most suitable), and to wash the paper under the tap after the reagent has acted for a few minutes. The drawback of the test is that it damages the document.

Another test, which may be applied without injuring a document, is to moisten the paper between folds of damp blotting paper, and then to expose it to the vapour of ammonium sulphide. This will detect lead and the compounds of other metals which form dark sulphides.

Finally, special tests for particular substances may be applied to different parts of the paper by means of a feather dipped in the particular reagent, such as, for example, a solution of ferric chloride for ferrocyanide, tannin, gallic acid, thiocyanate, salicylic acid, etc.; alkali for pyrogallol; and so on.

Dusting the surface lightly with fine graphite and then pressing the paper in a copying press will detect writing in sugar, dextrin, or colourless gums, by causing the powder to adhere to the characters, but this method tends to smudge the paper.

[1] *Loc. cit.*, p. 123.

If it has been found that a cobalt salt is present, it may be a matter of subsidiary importance to determine whether the chloride or nitrate was used for the writing. This may be ascertained by applying a drop of sulphuric acid and a crystal of brucine to part of the writing, when a blood-red coloration will be obtained, if a nitrate is present. If a negative result is obtained, a drop of nitric acid, followed by silver nitrate, may be applied, care being taken that the drop retains its globular form. In the presence of a chloride the drop will immediately become opalescent, and the change will be plainly visible with the aid of a magnifying glass.

Subsidiary Evidence of Secret Writing.—In criminal cases, such as the fraudulent use of vanishing inks on betting accounts mentioned above, it may be necessary to prove that particular preparations found in the possession of the accused person, had been used, or were capable of being used, for this purpose.

In the public trial of the German agent Kuepferle (*Rex* v. *Kuepferle*),[1] evidence of this nature was given by the writer. A cut lemon, a pen, and a bottle of formalin had been found in the possession of the prisoner. The nib of the pen had adherent particles of vegetable matter which were plainly visible under the microscope. When the metal was washed with a few c.c. of distilled water a solution was obtained which gave a reaction with ammonium vanadate, which the writer[2] has shown to be characteristic of fruit acids.

Another portion of the washings gave Hehner's reaction for formaldehyde (carmine zone with phenol

[1] *Times* Report, May 15, 1915.

[2] *Analyst*, 1903, xxviii., 146.

and sulphuric acid). The cut lemon showed a place where some pointed object had been inserted, and, on applying a few drops of potassium ferrocyanide solution to that spot, a deep blue coloration was obtained, whilst other parts of the lemon gave no reaction. From this the inference was drawn that an iron object, such as a steel pen, had been thrust into the lemon, the acid juice from which had dissolved some of the iron. The appearance of the pen was consistent with the conclusion that iron could have been dissolved from it in this way, for the original protective lacquer had been worn off, and the surface of the metal showed considerable corrosion, such as would be produced by the action of acid.

Secret writing had been developed by means of heat in a letter signed by the prisoner, and the brown appearance of the characters agreed with that of writing done with a mixture of lemon juice and formalin.

BIBLIOGRAPHY.

Dennstedt and Voigtländer.—*Baumert's Lehrbuch der Gerichtlichen Chemie*, Brunswick, 1906.

Guareschi.—*Gli Inchiostri da Scrivere*, Milan, 1915.

Lucas, A.—*Legal Chemistry and Scientific Criminal Investigation*, London, 1920.

Lucas, A.—*Forensic Chemistry*, London, 1921.

Mitchell, C. A., and Hepworth, T. C.—*Inks: Their Composition and Manufacture*, 2nd Edition, London, 1916.

Mitchell, C. A.—*Cantor Lectures*, Royal Society of Arts, 1922.

CHAPTER IX.

TYPEWRITING AND PRINTING.

Historical.—Although it was not until the latter part of the nineteenth century that the typewriter became established as an instrument of everyday use, numerous attempts had previously been made to produce a writing machine. The earliest claim to an invention of the kind is to be found in the English Patent No. 395, of 1714, granted to Henry Milly, in which the invention is described as "An Artificial Machine or Method for the Impressing or Transcribing Letters, Singly or Progressively one after the other as in Writing, whereby all writing whatever may be Engrossed in Paper or Parchment so Neat and Exact as not to be distinguished from Print." Unfortunately, as is usually the case in early patent specifications, no details of the construction of this machine are given, and the writer has not found any contemporary references to its use.

In 1829 a patent for a writing machine was taken out by Burt in the United States, whilst, in 1833, a machine was patented by Progrin in France, and another U.S.A. patent is dated 1843; but none of these inventions appears to have been commercially successful, and the birth of the typewriter of to-day began with the U.S.A. Patent No. 79,265, of 1868, taken out by Sholes. This was developed into a practicable machine by 1873, and, in 1878, was transferred to the Remington Company.

Machines and Types.—With but few exceptions, the numerous makes of machines, which are mainly of American origin, use a keyboard for imprinting the characters upon the paper, the types being supported by a bar or attached to the surface of a wheel or segment thereof, the rotation of which brings the respective type into the correct position with regard to the paper.

In certain machines, such as the Yost, the types are inked upon a pad, whilst in others, such as the Oliver, a travelling ribbon is used. This difference may be an important factor in the identification of typewriting.

The construction of a particular machine may have an important bearing upon the question of the identification of the origin of a specimen of typing, since certain deviations from the normal characteristics may be due, not to an inherent defect in the machine, but to variations produced by temporary causes, such as the touch of an unskilled operator.

The form of type fitted to modern typewriters is, in most cases, that known as "Pica," which, it should be noted, does not necessarily connote a standard size, as does the "Pica" in printers' type, but varies considerably in size in the case of different machines. Other forms of type in less common use include "Greatprimer Roman," which is a larger type; "Gothic," a very large form used on special machines for addressing parcels; "Medium Roman"; and "Elite," a very small form.

Differences in the size of type, which are sometimes not readily visible to the unaided eye, may frequently be demonstrated by means of micro-measurements, or by photography beneath ruled glass.

Differences in Form of Type.—Whilst many type-makers show a general agreement in the form of the type used, there are generally certain distinctive features in connection with particular individual letters. For instance, the tail of the " y " may be looped in a different manner, or the final stroke of the " r " may show a different curvature, and so on.

Sometimes a typewriting company introduces a

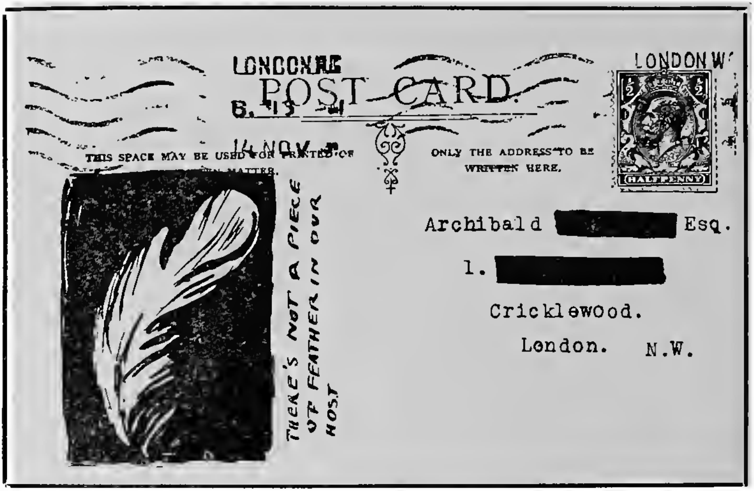

Fig. 46.—Typical " White Feather " Post Card. Machine Identified by the Typing.

completely new form of type, and this may frequently be of importance as a means of identifying the approximate date of a specimen of typing. For example, in 1906 a Remington machine was issued in which, *inter alia*, the " r " was made with a more pronounced final curve than previously.

Another factor which may be of importance in identifying a particular machine is that in some cases, when type has been repaired, type of a different form from that belonging to the original machine has been used.

Differences in Spacing.—Apart from differences in the design and size of the founts, certain differences are to be found in the spacing of the letters. As a rule, ordinary pica type occupies ten letters to the inch, and medium Roman the same space, but in the case of the latter

Fig. 47.—Ribbon showing Threads (Kinsley).

type some manufacturers use only nine. Usually there are twelve letters of Elite type to the inch, but in some machines there may be fourteen.

Defects and Faults in Type.—Whilst the general class to which a machine belongs may be identified by the general character (see Fig. 48) of the impression (*e.g.*, the ribbon marks as in Fig. 47), and the size and form of the type as determined by microscopic measurements and photographic enlargements, it is necessary to take into consideration the accidental features to form a conclusion as to the individual machine.

Thus, it will be found that the alignment in the letters will differ in the case of different machines, some dropping slightly below the line and others projecting too far above it, whilst the angle of the different letters, in relation to a line at right angles to the base, will also show pronounced differences, which tend to become accentuated with use.

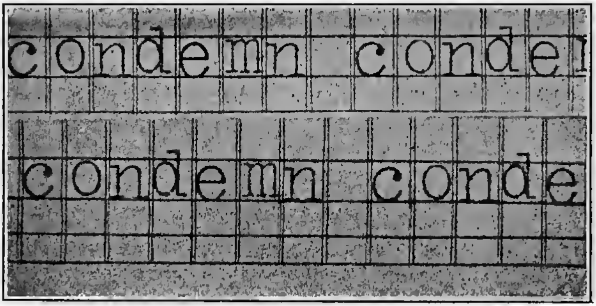

Fig. 48.—Differences in Position in Typed Letters.

These differences of position may be readily demonstrated by Osborn's method of photography beneath a glass ruled in squares of the right dimensions, as shown in Fig. 48, which is reproduced here by permission of the late Mr. J. Kinsley, of New York.

This is also clearly shown in Fig. 49, which shows enlarged photographs of typewritten words. These words formed part of an anonymous letter received by a clerk accusing him of having taken a sum of money, and threatening him with exposure if he did not return the amount.

Suspicion pointed to a certain person as the sender of the letter, and the suspicion was proved to be well founded by the results obtained on typing the words upon his machine. Note, for example, the spacing between the " r " and " e " and the " r " and " n."

Letters which are battered, or are slightly defective

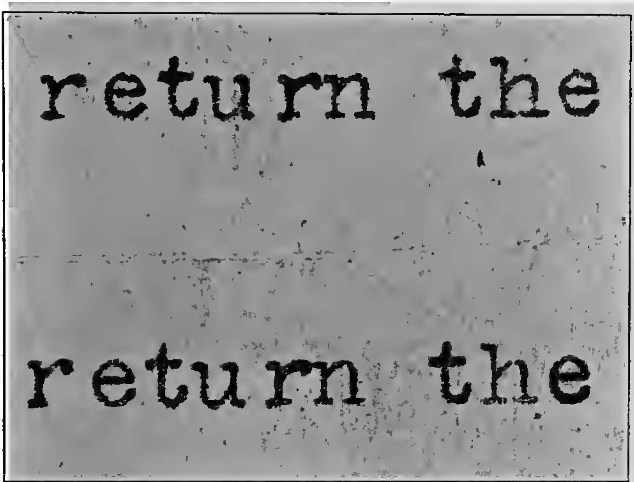

Fig. 49.—Typewritten Words, showing differences in Spacing and Position.

in some portion or other, are not infrequently present, even in new machines, whilst they are almost invariably found in machines which have been in use for some time. That is to say, parts of letters become worn and no longer produce a perfect impression.

In the Risley case, tried in 1911, in the Herkimer

County N.Y. Supreme Court, evidence was given by the representative of a typewriter company that the defendant, Risley, had left with the firm an Underwood machine with instructions to make it produce imperfect impressions similar to those given by Risley's machine. The repairer admitted, however, that, notwithstanding all his efforts with chisel and file, he had not succeeded in producing the same defects (see Fig. 50).

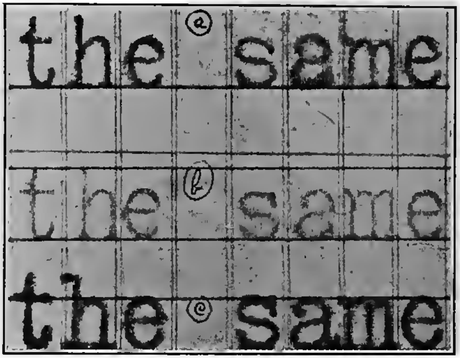

Fig 50.—Exhibits in Risley Case: (*a*) Words from Risley's copy of disputed affidavit. (*b*) Work of Risley's machine. (*c*) Underwood machine altered to produce faults of Risley's machine.

Unevenness of Impression.—Owing to the fact that, in most typewriters, the type strikes upon a curved surface of paper, which is rolled round the platen or roller of the machine, they are made with a slightly concave face. Hence, they will usually show heavier or lighter printing in some parts of individual letters, since the slightest alteration of position affects the evenness of the impression. For example, in the case of certain machines certain letters will appear dark upon the right and pale upon the left, whilst in the case of another machine of the same make the reverse will be seen.

In the Risley trial evidence was given by Professor Snyder as to the probability of there being two machines having type of the same size and design, and showing identical defects, and, expressing the chances numerically, he estimated them at one in 3,000,000,000,000.

PRINTING.

Historical.—Reference has already been made in a previous chapter to the use of wooden blocks for printing, and to the so-called block-books which were produced in this way by a sort of engraving process at a very early period.

The first instance of the use of movable type as distinct from wood blocks occurs in *Letters of Indulgence*, issued by Pope Nicholas V. in 1454. Books thus printed were produced at Mainz in about 1454 to 1457, at Strasbourg in 1460, and at Nüremberg in 1470, whilst, after 1477, the art spread to all the principal towns on the Continent.

It is a characteristic of these early printed books that attempts were made to reproduce all the distinctive features in the MSS. in question. Other peculiarities are that blanks were left for the subsequent addition of coloured initial letters by the rubricator, these places being shown by means of small letters, termed "initial directors," placed near the margins of the pages. According to Hessels,[1] hyphens were irregular in form and were placed beyond the printed margins, but after 1472 they became more regular in shape. Catchwords

[1] Art. "Typography," *Encyclopædia Britannica.*

(*custodes*) were first used in 1469 in a book printed at Venice, whilst pagination dates back to 1471, the numbers of each leaf being placed at the end of a line in the middle of each right-hand page.

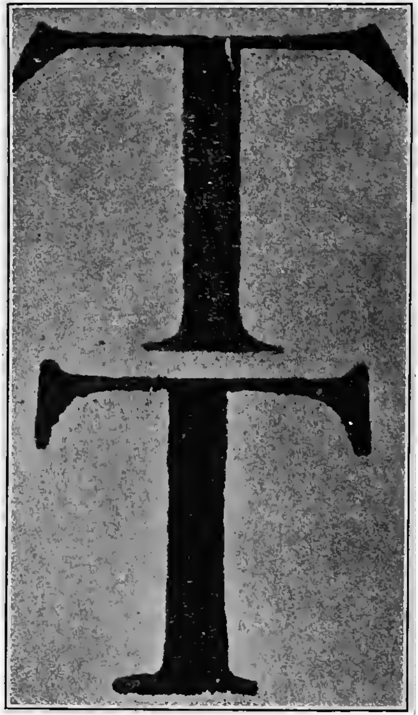

Fig. 51 —Differences in the Form of Printing Type.

Identification of Printing.—Many of the remarks made with regard to the types of typewriting machines are also applicable to printing type, although the various founts have become much more standardised in form. The main features, therefore, which will serve to distinguish between two pieces of printing are slight differences in the form of the letters, faults of alignment, and defective letters.

In an American case a forged receipt was produced by an accused person, who represented it to be a genuine letter-heading received from a French lawyer. The latter admitted that the letter-head must be genuine,

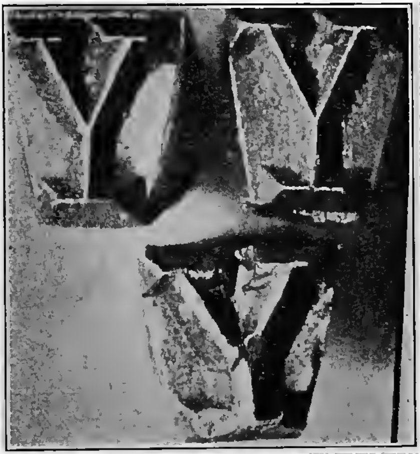

Fig. 52.—Defects in Printing Type.

but contended that the receipt itself had been forged. Further examination, however, proved that the heading had been copied by photography from a genuine letter.

The difference in form of printing type is shown in Fig. 51, for which the writer is indebted to the late Mr. J. Kinsley. The upper letter "T" is enlarged from a letter-head upon which a forged will was written, whilst the lower "T" is from a genuine letter-heading. The defect in the base of this lower letter is a notable feature.

Another example of defects in printing type is shown in Fig. 52, which is due to Mr. Osborn. This represents the enlarged faces of three types cast from the same matrix. The first is new, whilst the second shows a single damaged place, and the third is badly chipped. The imprints from each of these types could be readily differentiated.

BIBLIOGRAPHY.

HESSELS, J. H.—Art. "Typography," *Encycl. Britannica.*

HESSELS, J. H.—*Haarlem the Birthplace of Printing*, London, 1887.

JACOBY, C. T.—*Some Notes on Books and Printing*, London, 1892.

JOHNSON, J.—*Typographia, or the Printers' Instructor*, London, 1824.

KINSLEY, W. J.—*Typewriting Identifications*, New York, 1911.

MARES, G. C.—*The History of the Typewriter*, London, 1909.

OSBORN, A. E.—*Questioned Documents*, Rochester, N.Y., 1910.

CHAPTER X.

STAMPS, SEALS, AND ENVELOPES.

THE examination of the subsidiary points in a disputed document may often throw unexpected light upon the question at issue, and microscopical, photographic, and chemical methods should be applied to any adhesive stamps or seals, embossed stamps, or impressions made with metal or rubber stamps.

Postage and Receipt Stamps.—The examination of postage stamps from which the cancellation marks are supposed to have been removed, does not as a rule come within the scope of the work of the non-official chemist, such examination usually being made by the Government chemists. In certain cases, however, where no fraud upon the revenue has been intended, attempts have been made to remove or falsify a cancellation mark with, for example, the object of corroborating a false date written upon the letter contained in the envelope.

Since an ink of carbon and oil, similar to printer's ink, is used for cancelling postage stamps, the removal of the mark is practically impossible without leaving some indication of erasure or treatment with a solvent reagent for the oil in the ink. Such indications may be readily demonstrated by means of an enlarged photograph.

In one case within the writer's experience a fraudulent claim against an insurance company was detected by the projections upon the torn edges of two receipt stamps. As evidence of the losses in the alleged burglary three receipts for jewellery were produced, dated in December, January, and February. Examination of the stamps upon the first and third of these showed that the

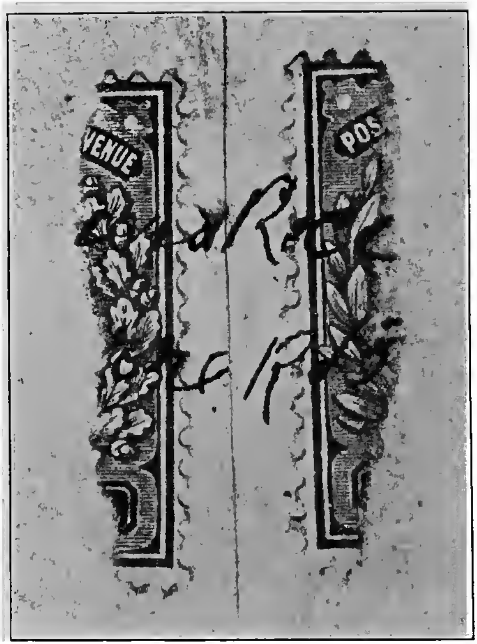

Fig. 53.—Coinciding Edges of Receipt Stamps.

right-hand edge of the earlier one coincided exactly with the left-hand edge of the second (Fig. 53). Wherever, in tearing the stamps apart, a short projection had been left on the one there was a corresponding long projection upon the other. In fact, throughout the whole of the seventeen projections there was perfect coincidence in every detail. The chances against such complete coincidence by accident were enormous, and it was highly improbable that the jeweller should have kept one of two adjacent stamps for three months, and have then affixed it to a second receipt given to the same person. The only other possible conclusion was that the two stamps had been put, at the same time, upon receipted bills dated three months apart, and that the jeweller had been acting in collusion with the claimants.

Embossed Paper Seals.—The seals of lead or wax, which were formerly attached to documents, are now frequently replaced by seals of coloured paper, which can be attached to the paper.

The nature of the pigment in the seal may afford information as to whether or no it is genuine. For example, in the case of a forged document of foreign origin, examined by the writer, the colour of the seal was seen to be of a different shade of red when examined with the tintometer, and the pigment behaved differently when treated with chemical reagents. Thus, the red colour of a genuine seal was changed to a deep maroon colour by potassium hydroxide, but was hardly affected by nitric acid, whereas the pigment in the forged seal became orange with potassium hydroxide solution, and very pale yellow with nitric acid.

Embossed Impressions.—These are most suitably photographed with a strong side light, so as to throw the detail into relief. Even when the stamp has been rendered illegible by pressure, the characters may still be rendered visible in this way. If, however, the paper has been rubbed, the fibres which have been raised by the friction will cast a shadow which will interfere with the photography.

In such cases Dennstedt and Voigtländer [1] recommend that the surface of the paper should be moistened and exposed to the air to dry, but without any pressure being applied. This causes the fibres to subside, and by repeating the process several times, and again taking a photograph, it is frequently possible, by comparing the negatives, to decipher the original characters.

Osborn [2] finds that the best method of photographing an uneven surface, such as a pencil indentation without pigment, a postmark without ink, or stamped seal impressions on white paper, is partly to cover the space between the lens and object, and to find the best angle for illumination from one side to obtain a perfect outline. For this purpose the light may be admitted through a narrow slit.

He also recommends the use of stereo-photomicrographs for bringing out the fine detail in such impressions.[3]

Impressions from Rubber Stamps.—The impressions made with rubber stamps in aniline inks are sometimes transferred to another document. To effect this a hard-boiled egg, or a gelatin graph, may be used, so as to obtain a faint, though still readable, impression.

In such cases the traces of gelatin, albumin, etc., also transferred, tend to alter the colour of the paper, and such alterations may be shown by the aid of photography.

In other cases Dennstedt and Voigtländer [4] have found iodine vapour a useful reagent, since it indicates

[1] *Loc. cit.*, p. 144.
[2] *Loc. cit.*, p. 65.
[3] *Loc. cit.*, p. 48.
[4] *Loc. cit.*, p. 129.

action of the substances upon the paper. The reagent should be applied to both sides of the document.

The aniline dyes in stamping inks may be bleached by treatment with various reagents, such as hydrogen peroxide, acid and alkali used alternately, etc. Such erasure may sometimes be detected photographically, or by treatment with iodine vapour.

If one impression has been stamped above the other, it is rarely possible to be certain which is uppermost, even when the pigments are of different colours, or when one consists of aniline ink and the other of printer's ink, since the glycerin or other fluid medium causes the two pigments to mix.

The same remark applies to a stamped impression above writing ink or *vice versâ*. In the experience of Dennstedt and Voigtländer[1] a probable conclusion can only be drawn, in the case of writing ink beneath, in those rare instances where the stamping ink is so thick that the aniline dyestuff shows a heavy layer with metallic lustre. In like manner, it is only when the stamping ink is very oily and takes up but little pigment that a writing ink can be seen to be above the other ink.

There is a similar uncertainty in the case of pencil writing, because the pigment of the stamping ink completely masks the silver striations of the pencil pigment, which, whether above or below the stamping ink, has the appearance of being uppermost (*cf.* p. 132).

Impressions from Metal Stamps.—Many of the remarks made with regard to the impressions from rubber stamps are also applicable to impressions from metal stamps,

[1] *Ibid.*, p. 132.

of which the devices used for cancelling postage stamps are typical.

Lucas[1] states that it is a common practice in Egypt and the East generally to use an official impression from a metal stamp in place of signing a signature, and that such impressions are occasionally forged by transference, especially when an aniline ink is used.

He mentions that in the Egyptian archives there is a seal impression in black ink on a document of A.D. 1770, and seal impressions in green ink on various documents dating back to 1869.

A systematic examination of postage cancellation marks may sometimes give valuable information. For example, in a recent case within the writer's experience, an anonymous letter was received at an office, and had apparently been registered abroad. It was found, however, that the cancellation lines stopped abruptly at the edges of the postage stamps, that the circular date stamp passing over the two stamps was not quite true in form, and that where it extended to the paper there was an indentation such as would be produced by ruling with a pointed instrument round a coin. These facts confirmed evidence from other observations that the anonymous letter had originated in the office itself, and that the stamps had been removed from a genuine foreign registered letter, and transferred to the envelope containing the anonymous document.

Cancelling Perforations.—The perforated devices and letters which are frequently used as safeguards have sometimes been filled in with pulp and fresh perforations made on the same ground. This may be readily

[1] *Loc. cit.* p. 99.

detected by the aid of the microscope and the camera. The example of this ingenious fraud, shown in Fig. 54, is reproduced by the permission of Mr. A. S. Osborn. In this case the figure punched in a cheque for $24 had been filled in, and fresh perforations representing $2,400 made on the same ground. A photograph by transmitted light afforded a clear demonstration of the forgery.

Envelopes.—It is sometimes necessary to determine whether there has been any tampering with an envelope, either in the post or subsequently. As a photographic test

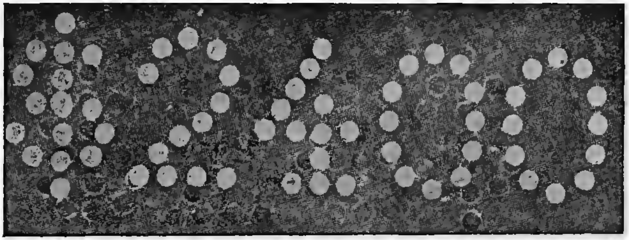

Fig. 54.—Substitution of new for old perforations.

Dennstedt and Voigtländer[1] recommend the following method:—The portion of the envelope to be examined is wrapped in moist filter paper and placed under a bell-jar, the treatment being continued until the papers can be separated without the application of force. The gummed portions are then photographed in direct and very oblique light, and, if a second adhesive agent has been applied, the surface will usually show irregular deposits, which are particularly noticeable by transmitted light.

[1] *Loc. cit.*, p. 138.

Chemical Tests.—When a different adhesive has been used for reclosing the envelope, it is frequently possible to detect the addition by the use of chemical reagents. A very dilute potassium iodide solution of iodine is useful for this purpose, since it gives a blue coloration with starch and a brown coloration with dextrin. Pure gum arabic gives a precipitate with basic lead acetate solution, and, unlike dextrin, its solution does not become turbid on the addition of oxalic acid. Dextrin is insoluble both in alcohol and ether.

The presence of casein or glue may be detected by means of the biuret reaction, which is applied by adding to the solution of the adhesive a few drops of a 2 per cent. solution of copper sulphate and then a few drops of a 5 per cent. solution of potassium hydroxide, a violet coloration indicating one of these products.

Certain office pastes contain zinc chloride as a hydrolytic agent to make the paste remain semi-fluid, instead of gelatinising. In such cases zinc chloride may be detected by means of microchemical tests for zinc and for chlorine.

Sealing Wax.—The earliest form of material used for sealing letters appears to have been bituminous composition, which was used in Egypt and various parts of Asia, and thence introduced into Rome. Other materials used for the purpose at an early period included pipeclay, and compositions of wax, pitch, gypsum, and fat.

The seals upon old official documents consisted of beeswax, and the name "wax" was retained when the resinous composition now known as sealing wax replaced beeswax for sealing letters.

Dobbie and Fox [1] examined mediæval seal impressions dating from the thirteenth to the sixteenth century, and found them to be composed either of pure beeswax or of a mixture of beeswax and a resin, which, in two cases, was ordinary resin. The red pigment in the red seals was vermilion, whilst the green consisted of verdigris, and the brown and black of a mixture of verdigris and organic matter.

The wax composing the Great Seal of 1350 showed all the usual physical and chemical characteristics of normal beeswax, whereas the wax of a seal of the thirteenth century had been decomposed by mould.

According to Tomlinson [2] the earliest known instance of the use of red sealing wax made of shellac and vermilion is on a letter written in 1554 to the Rheingrave Philip Francis von Dam from his agent in London, whilst other extant letters bearing seals are dated 1561 and 1563.

According to Beckmann (*Geschichte der Erfindungen*), the first reference in literature to the use of sealing wax is in a book of Garcia at Orto, *Aromatum et Simplicium*, printed at Antwerp in 1574, where it is mentioned that strips of *lac* were used for sealing letters.

The same authority gave a recipe for making sealing wax, which is taken from a book by Zimmermann, of Augsburg, 1579. The following is a translation of this from the original German:—"To make hard sealing wax, called Spanish wax, letters sealed with which cannot be opened without breaking the seal; take fine transparent resin, as colourless as can be obtained,

[1] *Journ. Chem. Soc.*, 1914, cv., 795.

[2] *Cyclopædia of Useful Arts*, 18, vii., p. 598.

and melt it over a slow coal fire. When it is completely melted remove it from the fire, and for every pound of resin add 2 ounces of finely powdered vermilion, and stir the mixture. The whole is then left to cool or is poured into water. In this way you will obtain fine red sealing-wax. If black wax be required, add lampblack to the resin. With smalt or azure you have it blue; with white lead, white; and with orpiment, yellow."

For a long time sealing wax was made almost exclusively in Holland, and the Dutch mark, "Brand well en vast houde," was subsequently adopted by English makers, but eventually *Dutch wax* became the name of poorer qualities.

In later preparations of sealing wax red lead was used instead of vermilion, ivory black for black, massicot or turpeth mineral for yellow, whilst, for gold sealing wax, powdered yellow mica was used. Venice turpentine was originally added to render the final product less brittle, but, in the case of modern waxes, this is usually replaced by a solution of ordinary rosin in oil of turpentine.

Chemical Examination of Sealing Wax.—*Ash* is estimated by igniting a weighed quantity of the wax and resins (shellac and colophony) by extracting 2 to 3 grms. of the sample with ether and then with alcohol, and drying and weighing the residue of insoluble matter.

The red insoluble residue may consist of vermilion, or, in commoner waxes, red lead. In the former case it will give the reactions for mercury when dissolved in strong hydrochloric acid, whilst red lead will change its colour to buff on treatment with dilute hydrochloric acid.

The application of chemical methods in forensic work may be illustrated by the case of *Rex* v. *Fink*, in which the accused asserted that alleged alterations upon a cheque had not been made by him, but that the cheque had been tampered with in the post.

Now, it had been sent to the post in a registered sealed envelope, and had been followed by a second letter, also in a sealed registered envelope. A stick of red sealing wax was found in the possession of Major Fink, and the close agreement between the composition of this wax and of the seals upon the letters left no room for doubt as to the origin of the latter. At the same time an analysis was made of the wax from the post office where the letters had been posted, and of various other commercial specimens of sealing wax, taken at random, and the results thus obtained are shown in the following table:—

Sealing Waxes.	Ash.	Ash Insoluble in Hydrochloric Acid.	Sulphate in Ash.	Resins.	Vermilion.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Major Fink's wax, .	38·20	16·56	13·14	46·71	32·59
Seals on letter I., .	38·29	16·43	13·44	46·77	32·25
,, ,, II., .	38·26	16·58	13·58	46·57	..
Commercial wax I., .	57·37	37·67	20·79	..	present.
,, II., .	28·66	23·92	3·27	..	,,
,, III., .	73·82	73·08	nil.	..	,,
Seal on parcel, . .	19·64	Trace.	..	..	,,
,, letter, . .	40·40	12·59	10·25	..	,,
Wax from post office, .	50·11	Consisting chiefly of Iron Oxide.			Nil.

After hearing evidence upon this and other points the jury found the prisoner guilty.

Microscopical Examination of Seals.—Lucas[1] calls attention to the importance of minute examination of the seals upon documents. In certain cases he has been able to prove that the seal was composed of two distinct layers of wax, one above the other, whilst the presence of black carbonaceous matter derived from a match may occasionally afford a significant clue of the addition of a subsequent portion of wax. Or, in other cases, spots or streaks of wax of a different colour may be observed.

In a case recorded by him a large sum in bank notes had been stolen from an envelope, the letter being then resealed after some of the notes had been replaced. It was found that the wax seals showed two distinct layers of wax, and that one of the impressions contained particles of dark blue wool. The wax agreed in colour and composition with that of the firm who had sent the letter, but differed from the wax used in the post office, and from wax in the possession of the recipient of the letter. The woollen fibre found in one of the impressions corresponded with the material in the coat of one of the employees of the firm sending the letter, and the right-hand sleeve of this coat had a frayed edge. From these and other facts the conclusion was drawn that after the letter had been sealed down, it had been re-opened, and again sealed with the firm's own seal.

Forged Seals.—Various methods of imitating seals have been described, such as making impressions in bread-pulp or in paper-pulp, etc., but these lack the

[1] *Loc. cit.*, p. 155.

sharpness of detail of the original, and are more or less distorted.

Dennstedt and Voigtländer[1] demonstrate such an imitation by photographing both seals on a colour-sensitive plate, with the aid of a colour screen. A glass positive is printed from this negative, cut in half between the two seals, and the two portions superimposed. If the questioned seal is genuine, it should coincide exactly with the other when examined by transmitted light, due allowance being made for the variations due to difference of pressure upon the wax, etc. When there is a pronounced difference between the two seals it may be made clearer by means of enlargements. Osborn[2] has used stereoscopic photomicrographs for this purpose.

The question of such reproduction of seals came prominently before the Courts a few years ago in what was known as "The Great Pearl Case."

BIBLIOGRAPHY.

Bromley, H. A.—*Outlines of Stationery Testing*, London, 1913.

Dennstedt and Voigtländer.—*Baumert's Lehrbuch der gerichtlichen Chemie*, Vol. ii., Brunswick, 1906.

Dobbie, J., and Fox, J.—*Journ. Chem. Soc.*, 1914, cv., p. 795.

Lucas, A.—*Legal Chemistry and Scientific Criminal Investigation*, London, 1920.

Lucas, A.—*Forensic Chemistry*, London, 1921.

Mitchell, C. A.—*Knowledge*, 1912, xxxv., p. 210.

Osborn, A. S.—*Questioned Documents*, Rochester, N.Y., 1910.

Tomlinson.—*Cyclopædia of Useful Arts*, vol. vii., p. 598.

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[1] *Loc. cit.*, p. 127.

[2] *Questioned Documents.*

CHAPTER XI.

FINGER PRINTS ON DOCUMENTS.

ONE of the most important contributions which science has made to criminology has been the utilisation of the forms of the texture of the skin for the identification of the individual. The systematic classification of hundreds of thousands of impressions taken from the tips of the fingers of different persons, and the comparison of their minute characteristics with those of other prints, has brought cumulative proof, which now amounts to practical certainty, that no two human beings will show all the same distinctive features of the patterns formed by the ridges upon their fingers and thumbs. This system of identification has been adopted by the police authorities all over the world, and has displaced the Bertillon system, which is based upon the tabulation of exact measurements of selected physical characteristics.[1]

It does not come within the scope of this book to discuss the subject at length in all its bearings, but, inasmuch as it may frequently be necessary in future to detect a latent impression upon paper, or rapidly to identify a finger print used as a safeguard upon a document, it will not be out of place to give a brief summary of the work that has been done, more especially

[1] An outline of Bertillon's system, condensed from his original pamphlets, will be found in my book, *Science and the Criminal*, pp. 51-54.

in this connection, and to tabulate in a convenient form references to the original communications.

Nature of Finger Prints.—The skin on the palms of the hands and soles of the feet shows a corrugated texture made up of minute ridges which sweep over it in broad curves, here branching off in fresh directions, and there uniting with other lines to form well-defined patterns. On the tips of the fingers and thumbs, in particular, these patterns become concentrated into small areas, and are thus more convenient than other parts of the hand for obtaining records of the texture.

It is the reverse impression of these ridge areas, produced in printing ink or other suitable medium, which is now usually connoted by the term "finger prints." These impressions may be either positive or negative according to the amount of pigment applied to the fingers and the degree of pressure used. That is to say, the ridges may appear dark and the furrows and pores on the ridges light, or the furrows and pores may be dark and the ridges light (a negative print). In some cases the prints are of an intermediate character.

The probable functions of the ridges are discussed at some length by Galton, with references to physiological authorities.[1]

Persistence of the Markings.—The distinctive patterns of the ridges are discernible on the fingers of the embryo child,[2] continue unchanged as regards their essentials throughout life, and after death are not obliterated until the skin itself has decomposed. Gross [3] states that the finger tips of a mummy in the Vienna museum show

[1] *Finger Prints*, 1899, pp. 60-63. [2] *Loc. cit.*
[3] *Handbuch der Untersuchungsrichter.*

distinct papillary ridges. There is only one case on record where any change has been observed in the pattern of the skin of the same individual at different periods. In this unique instance, recorded by Galton,[1] a single forked ridge which was present in the finger print of a child two and a half years old had become filled up at the age of 15. Sir William Herschel [2] gives a further

Fig. 55.—Prints of Sir W. Herschel's Right Thumb in 1861 and 1914.

print from the same finger in 1913 (*i.e.*, 36 years after the first impression), and this shows no further alteration in the form of the pattern. The ridges still coincide with those of the baby's finger print in 42 points, and differ only in this minute detail.

The longest record of persistence in the ridges is that

[1] *Loc. cit.*, p. 93.

[2] *Origin of Finger Prints*, 1916, p. 27.

afforded by the finger prints of Sir William Herschel himself, and they are reproduced here by his permission. The first print was made in 1860 in India, and the second in 1914, whilst a repeat was sent to the writer by Sir William Herschel in 1916 shortly before his death. In this interval of 56 years there has been no essential change in the form of the pattern, although in places the continuity of the lines has been broken by disintegration of the skin surface due to old age.

Permanence of the Ridges.—In 1880 systematic experiments were made by Dr. Faulds to ascertain whether it was possible for the ridges to change their positions under accidental influences.[1] After an impression of the finger tips had been taken, the skin was rubbed with various powders until quite smooth and was then allowed to grow again. The characteristics of the prints taken from the new skin agreed exactly with those of the original prints. The effects of "peeling" after fever and of burns were also studied by Faulds, who found that neither had had permanent influence on the patterns.

Galton[2] gives two good instances of the remarkable permanence of the scars produced by a cut, and the present writer has shown that the effect of a cut appears plainly as an irregular break in the continuity of the ridges after an interval of 30 years.[3]

The effect of tools being constantly handled is to produce callosities on the fingers which will appear in the prints, and Galton[4] gives an illustration of the finger print of a tailor showing the temporary

[1] *Knowledge*, 1911, xxxiv., p. 137.

[2] *Finger Print Directories*, 1895, p. 103.

[3] *Science and the Criminal*, p. 57.

[4] *Finger Prints*, p. 59.

destruction of the ridges caused by the friction of the needle.

Classification of the Ridges.—It is outside the scope of this book to give a detailed outline of the methods of classifying finger prints, but reference may be directed to the works mentioned in the bibliography at the end of this chapter. The first scheme of systematic classification of the ridges was that of Purkinje, who, in 1823, read a treatise [1] on the subject before the University of Breslau. This made no pretension to the identification of individuals, but was concerned only with the medical aspect of the question.

In Purkinje's system the curves were grouped into nine classes differentiated by the forms of the cores within the pattern.[2]

No further system of classification appears to have been attempted until 1888, when Faulds devised a method, an outline of which was published in 1905.[3]

Galton discarded Purkinje's system and grouped the patterns into three main groups termed *arches*, *loops*, and *whorls*, with some transitional forms and rare patterns.[4] His system of indexing is described at length in a later book.[5]

Finally, Sir E. Henry devised a modification of Galton's and Fauld's systems, which has simplified the whole classification, and is now exclusively used by the police authorities in this country.[6]

[1] *Commentatio de Examine physiologico Organi Visus et Systematis Cutanei*, Breslau, Dec. 22nd, 1823.

[2] See Galton, *Finger Prints*.

[3] *Guide to Finger Print Identification.*

[4] *Finger Prints*, pp. 64-68.

[5] *Finger Print Directories*, 1895.

[6] *Classification and Uses of Finger Prints.*

In this system, four main groups are used—viz., *arches*, *loops*, *whorls*, and *composites*, the last including combinations of the other three groups or transitional forms. Subdivisions are made into patterns with characteristics in common, such as "central pockets" and "accidentals," and further differentiation is effected by counting the number of ridges between two fixed points in the patterns.

A valuable method of coding the characteristics of finger prints has been devised by Wilder and Wentworth.[1]

Value of Prints as Evidence.—From a mathematical calculation of the chance against a given single finger print exactly resembling any other print, Galton[2] estimated that it was less than 1 to about 64 thousand millions. Assuming the human race to number about sixteen thousand millions, he concluded that it was a smaller chance than 1 to 4 that there should be exact similarity between any two prints from single fingers, whilst, if the comparison were extended to two fingers from each person, "the improbability of 1 to 236 becomes squared, and reaches a figure altogether beyond the range of the imagination."

At first the Courts were chary of accepting the evidence of identity furnished by finger prints as absolutely conclusive, and it was only after it had been shown to be correct in many striking instances, and never proved to be inaccurate, that doubts were no longer expressed, and that it was realised that more

[1] *Personal Identification*, p. 234.

[2] *Finger Prints*, p. 110; *Finger Print Directories*, p. 10.

reliance could be placed upon such testimony than upon identification by eye-witnesses.[1]

Finger Prints as Safeguards on Documents.—It is to Sir William Herschel that we owe the first suggestion of the use of finger prints on documents as a safeguard against fraud. It occurred to him in 1858, when entering into a contract with an Indian native, that an imprint of the hand of the latter upon the back of the document might make the transaction appear more solemn. The idea arose out of the fact that the natives were in the habit of dipping the tip of one finger into the ink and applying it to the paper as a ceremonial act.

The ceremonial use of a hand print in vermilion on old State documents in Japan is mentioned by Galton.[2]

A much more distinctive use of a finger print on a document is that adopted by Chinese bankers for marking bank notes. An imprint of the finger print is made partly upon the note and partly upon the counterfoil, so that a ready method of testing the coincidence of the two sections is provided. This method, however, is intended to identify, not the banker, but the note itself, and is obviously an effective safeguard against forgery.

Bewick's Finger Prints.—Bewick, the engraver, was in the habit of using his finger print as a sort of sign manual in his books. Instances of this are to be seen in his *British Birds*, 1809, p. 190, and *The Receipt*, 1818.

Although Bewick obviously intended his finger print as a distinctive signature to his work, there is no evidence

[1] *Cf.* also Will's *Circumstantial Evidence*, 1912; and Fauld's *Guide to Finger Print Identification*, 50-52.

[2] *Loc. cit.*, p. 23.

that he was ever struck by the possibility of proving his identity by this means.[1]

The contract which Sir William Herschel made with the native Konai suggested the practicability of the method of identification purposes, and may be regarded as the first step towards the development of the modern finger print system.

Methods of Comparison.—In comparing two finger prints it is advisable to have them enlarged to exactly the same degree, from five to seven times being a convenient size. Galton[2] recommends placing the print with its face against a window pane or a retouching frame, and tracing the main ridges on the back with a pencil. He lays stress upon the importance of noting the *place* where a new ridge begins rather than the manner in which it appears to begin. This is owing to the fact that in the course of years the point of junction between two ridges may become slightly raised or depressed, so that it may either print more vigorously than before or escape printing altogether.

The Kew micrometer, as suggested by Faulds, is a most useful instrument for accurately measuring the lines and position of the pores in finger prints (see p. 12). For the purpose of demonstration it is useful to prepare enlarged photographic reproductions of the print upon the document, and of the finger print with which it is to be compared, and to mark with figures or letters the distinctive similarities on which reliance is placed. Mention should also be made of the accurate method

[1] This question is discussed at length in Herschel's *Origin of Finger Prints*, p. 34.

[2] *Decipherment of Blurred Finger Prints*, 1893, p. 8.

of comparison devised by Osborn,[1] in which the resemblances between the prints are clearly shown by means of photography beneath small squares accurately ruled upon glass.

In addition to this, tracings from the enlargements may be prepared, in which the agreement of the special ridges will be grasped by the eye as a whole much more readily.

Preparation of Comparative Prints.—The usual method of taking prints for purposes of comparison is the well-known printing ink process, but Ward's chemical method [2] offers many advantages over the older method. An ordinary slow gelatin photographic plate is exposed to light for a few seconds ; the finger is then well moistened with any usual photographic developer, and pressed firmly and evenly upon the surface of the plate for about fifteen seconds. The plate is next left to develop spontaneously, and is finally fixed with sodium thiosulphate and washed in the usual way. The image obtained shows the ridges white and the furrows and pores dark, with the finest detail clearly defined.

Use of X-Rays.—A new method of preparing finger prints has recently been devised by Beclere. The tips of the fingers are rubbed with finely powdered bismuth carbonate and then photographed beneath the X-rays. The negative shows the most minute details of the formation of the patterns, and all the pores are clearly visible in an enlargement. At the same time, the photograph shows the shape of the finger nails and the position of the bones of the fingers, and thus affords additional evidence of identity.

[1] *Questioned Documents.*

[2] *Analyst,* 1920, xlv., 129.

Latent Prints on Paper.—When the finger is pressed upon a polished surface, such as glass or steel, it leaves an imprint which may be seen by inclining the surface at a certain angle to the light, and may be rendered more visible by dusting it lightly with a fine white or coloured powder, and then removing the excess of powder with a fine camel's hair brush.

The first investigations of this branch of the subject in all its bearings were made by Dr. Henry Faulds, and his name must be linked with that of Sir William Herschel as the originator of the modern system of identification by finger prints.

In the case of finger prints on paper, the marks are much less visible than those upon glass or polished wood, and require different treatment for development according to the conditions.

Mechanical Development with Powders.—In the official English method of intensifying finger prints upon various polished objects, a mixture of chalk and mercury, the "grey powder" of the pharmacists, is used for dusting dark surfaces, whilst finely powdered graphite is used for light-coloured surfaces.[1]

Faulds[2] obtained good results with a mixture of graphite and lampblack, whilst other substances which have been recommended include ferric oxide, lycopodium powder, magnesium carbonate, and aniline dyestuffs, such as Soudan Red III.[3]

Locard[4] uses finely divided red lead, previously heated,

[1] E. R. Henry, *Classification and Uses of Finger Prints*, p. 106.

[2] *Guide to Finger Print Identification*, p. 65.

[3] Stockis, *Annales Soc. Med. Leg. Belge*, 1906, p. 7.

[4] *La Poroscopie*, p. 11.

for light surfaces and lead carbonate for dark surfaces. He has also found lead iodide to be an effective developer, although its colour is a drawback for photography.

The present writer has found methylene blue to be an efficient agent for developing latent prints on paper, provided it is quite dry and is lightly dusted over the surface and then blown off.

The results which this mechanical method is capable of yielding will depend upon the absorptive capacity of the paper. If the surface is very highly glazed, so as to be comparable with the surface of a japanned tin box, the prints seem to be quite permanent, and the writer has developed them quite sharply with methylene blue after a lapse of three years. But prints made on highly sized clayed paper, such as is used for book illustrations, although they could be brought out distinctly after several weeks, did not appear when treated in this way after three years. In the case of tracing paper the marks were developed clearly after three weeks, but could not be brought up after a few months, whilst the prints on ordinary card showed all their details for the course of a few days, but yielded only a faint outline after 18 days. Similar impressions on white blotting paper could be developed with sufficient detail for identification for an hour or two after being made, but showed only faint smudges, with no details, after about a week.[1]

To protect the prints from being smudged after development, Stockis [2] recommends coating the surface with a film of a solution of gum arabic, alum, and formaldehyde.

[1] *Analyst*, 1920, xlv., 122.

[2] *Loc. cit.*

Liquid Chemical Reagents.—Forgeot [1] describes experiments made by Aubert with special papers saturated with various salts, such as silver nitrate and mercuric nitrate, the prints being subsequently developed with appropriate reagents. When the hand is pressed on white paper and subsequently developed with 10 per cent. sodium thiosulphate solution containing a few drops of alcohol, the imprints are frequently developed as oily stains. The success of these methods, however, depends upon the time during which the hand was in contact with the paper, and so they cannot be recommended for the detection of accidental finger prints.

Osmic Acid.—Since imprints left by the finger invariably contain traces of organic matter, notably fatty compounds, the use of a solution of osmium tetroxide (osmic acid) suggests itself as a suitable reagent, and Faulds [2] and Gross [3] have both mentioned the possibility of using this reagent, but neither has given any particulars of the results which it gives.

The writer's experiments have shown that, by brushing the ordinary 1 per cent. solution over a print and leaving the surface moist, preferably while exposed to sunlight, reduction takes place and the ridge becomes black through the reduced osmium, while the furrows remain uncoloured.

The method is capable of showing up prints distinctly on moderately sized paper after the lapse of several weeks, but is less trustworthy than some of the other methods for long periods. Naturally it will not be effective in the case of prints on absorbent paper.

[1] *Archives de l'Anthropol. Criminelle,* 1891, vi., p. 387.

[2] *Dactylography,* p. 64.

[3] *Handbuch der Untersuchsrichter,* p. 598.

Ink Methods.—This objection also applies to the method of development by ink, which was first devised by Forgeot,[1] for the successful application of which a contact between the finger and paper of a few seconds at most is necessary. This method is based upon the principle that there is normally a slight secretion of oil on the fingers, and that in the impressions produced by them some of this oil will have been conveyed to those parts of the paper with which the ridges of the patterns have come in contact. Hence, when the place is subsequently treated with ink, the ridge markings will repel the liquid, whereas the intermediate furrows and the rest of the paper will be stained. In this way a negative finger print will be produced as opposed to the positive prints given by adhering powder or osmic acid, in which the ridges receive most of the pigment and the furrows remain relatively uncoloured.

Forgeot found that the best method of applying the test was by means of a brush, and that there was no advantage in diluting the ink. In his experience developing the print in an ink-bath was fatal to good results, as it produced unequal staining.

Faulds,[2] however, discarded Forgeot's method of brushing for development in a bath, and also found that ink diluted with water gave much better prints than the ink by itself.

It is highly probable that the cause of these discrepancies lies in the fact that writing ink is not a definite chemical composition, but varies widely in the proportion of its constituents. If comparable results are to be obtained by this method, it is necessary that a

[1] *Loc. cit.* [2] *Loc. cit.*, p. 67.

standard ink should be used, and the composition of this should be as simple as possible.

The drawback to the use of an ordinary iron-gall ink is that it is applied to the paper in an unoxidised condition, so that even those parts which appear very pale at first may eventually become much darker, with the result that it is difficult to control the final coloration.

Fig 56.—Print Developed after Three Years with "Swan" Ink.

The ordinary 1 per cent. solution of osmic acid produces inks with gallotannic acid and gallic acid, which have the advantage over iron-gall ink of attaining their maximum intensity of colour almost immediately after application to the paper. The gallic and gallotannic acids form violet-grey colorations, but the most suitable ink for developing finger prints is obtained by adding pyrogallic acid to osmic acid solution. In very dilute solution the osmic pyrogallate is at first violet, but almost immediately becomes greenish-blue, and when applied to paper gives a rich violet-black coloration.

Fig. 57.—Print Developed with Osmium Pyrogallate.

This reaction may be used as a very sensitive test for osmium tetroxide, the distinctive blue coloration being obtained on adding a trace of solid pyrogallic acid to a solution containing a few drops of 1 per cent. osmic acid solution. Ink of a suitable dilution for treating finger prints may be made by diluting 2 c.c. of the ordinary microscopic osmic acid reagent with the same quantity of water, and adding 0·05 grm. of pyrogallic acid. The liquid is ready for use immediately, and should be brushed over the paper with one broad sweep of a soft camel-hair brush.

These ink methods are applicable under varying conditions, and the writer has developed prints on highly sized paper after the lapse of three years, both by means of ordinary "Swan" ink (total solids, 2·98 per cent.) and by means of osmic pyrogallate.[1]

Reagents in the Form of Vapour.—The fact that finger prints may, and probably do, contain a certain amount of fat suggested the use of reagents which are absorbed by fat.

On the whole, iodine vapour is the most sensitive reagent. For example, a print made with light pressure on well sized paper could not be developed with methylene blue a month later, but was shown up sharply by means of iodine vapour, and was again redeveloped after three and a quarter years. A print on parchment paper, however, could not be developed after a few months, whilst prints on porous paper only gave moderately good results after a few hours.

The drawbacks of the iodine method are that the prints are fugitive, and, owing to their colour, are difficult to photograph. They may be fixed, to some extent, by treatment with solutions of silver salts, followed by thiosulphate, but lose a good deal of their sharpness in the process.

The writer has found that prints made with mercuric iodide vapour are considerably more stable. They are obtained by exposing the paper to vapour from a heated

[1] *Analyst, loc. cit.*

mixture of 4 parts of mercury and 5 parts of iodine. At first they are dark red, but the colour soon changes to yellow, probably through the formation of the yellow modification of mercuric iodide. An objection to this method is that the paper itself is sometimes stained a dark colour.

Bromine vapour only produces faint yellow prints, whilst iodine chloride vapour gives a much fainter coloration than iodine. Mercuric bromide is much less satisfactory than mercuric iodide as a reagent.

Since osmium tetroxide boils at about 100° C., it seemed probable that, applied in the form of vapour, it might prove a more sensitive reagent than when used as a solution. This was found to be the case, and prints full of fine detail were obtained by holding the paper over a basin in which a little of the 1 per cent. solution was boiling. The method will give good permanent prints on moderately sized paper or a postcard, but is not so sensitive as the iodine method. It effected no development of a print on highly sized paper after a period of three years. The prints produced by osmium tetroxide vapour are "positive," the ridges being grey, the furrows white, and the pores opening on the ridges dark grey to black.

Incidentally it may be mentioned that the method affords another test for osmium tetroxide. A slightly greasy finger print is made on glazed paper, which is then exposed to the vapour of the boiling liquid. A permanent print of the type described indicates the presence of osmium tetroxide.

It is probable that ruthenium tetroxide or volatile ruthenium salts, which also darken on contact with organic substances, would also give good results in the development of latent finger prints.

Faulds, in his experiments with the ink method, found that good results could often be obtained by adding creosote to the ink. This causes the reagent to run very rapidly over the surface of the paper, so that the period of contact is much shorter than when ordinary ink is

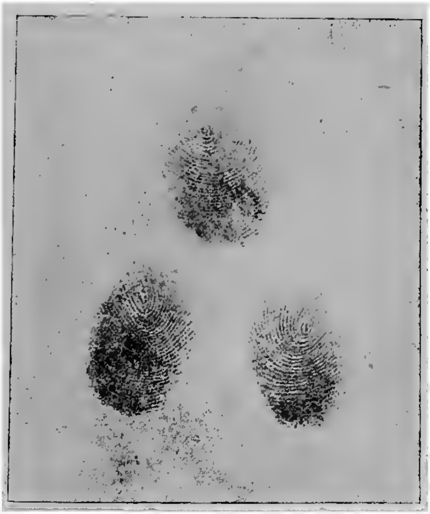

Fig. 58.—Finger Prints Developed with Osmium Tetroxide Vapour.

used. The differential staining is more pronounced when a finger print is recent than after it has been made for some time, and Faulds was able in this way to make some estimate of the approximate age of a print.

It is obvious that any such deductions from the behaviour of a print would only be possible if all the conditions, such as the behaviour of different kinds of paper, duration of impression, and effect of temperature upon the permanency of the prints, were known.

The comparative results obtained with reagents in the different forms of powders, liquids, and vapours appear from the results obtained in the writer's experiments to be more likely to afford a promising basis for estimating the relative age of finger prints.

Fig. 59.—Imprint of Hand on Polished Wood, showing Pores in the Skin.

Examination of the Pores.—The osmic vapour method is particularly suitable for determining the relative position, number, sizes, and shapes of the pore openings in finger prints. This recent development of the finger-print system is due to Dr. Locard, and the example shown in the accompanying figure is reproduced here by his permission.

This represents an imprint left upon polished furniture by two burglars, and the agreement between the pores of the imprints and of those on the skin of the suspects proved beyond doubt that these men were the culprits.[1]

Finger Prints in Blood.—There are several cases on record in which the imprint from a blood-stained finger has yielded conclusive evidence of the identity of the person who produced it.

In an instance of the kind mentioned by Gross,[2] the markings in certain blood stains on a paper journal were shown to coincide with the ridges on the fingers of a man who was supposed to have been murdered. This proof of the origin of the prints exonerated another man who had been arrested as the murderer.

The much-discussed case of Kaṇgali Charan has many points of interest, including the fact that it was the first occasion of a criminal having been detected by means of blood prints upon a document. Reproductions of the stain on the paper and of the finger prints of the accused, together with a summary of the points of resemblance, are given by Sir E. Henry.[3]

It was also proved by analysis that the stain consisted of mammalian blood, and it was suggested that the thief, in searching through the papers in the despatch case, had brought his blood-stained thumb into contact with the calendar.

[1] Locard, *La Poroscopie*, 1913.

[2] *Handbuch für Untersuchungsrichter.*

[3] *Classification and Uses of Finger Prints*, pp. 55-63.

The methods of identifying the presence or the nature of blood in finger imprints do not come within the scope of this book, but the reader may be referred to the outlines given elsewhere by the writer.[1]

BIBLIOGRAPHY.

FAULDS, H.—*Nature*, 1880, xxii., p. 165 (Skin Furrows of the Hand).

FAULDS, H.—*Guide to Finger Print Identification*, 1905 (Hanley).

FAULDS, H.—*Dactylography*, 1912 (Halifax).

FORGEOT, R.— *Arch. d'Anthropol. Criminelle*, 1891, vi., p. 387.

GALTON, F.—*Phil. Trans. Roy. Soc.*, 1891, clxxxii., pp. 1-23.

GALTON, F.—*Finger Prints*, 1892.

GALTON, F.—*Decipherment of Blurred Finger Prints*, 1893.

GALTON, F.—*Finger Print Directories*, 1895.

GROSS, H.—*Handbuch der Untersuchungsrichter als System der Kriminalstik*, 1908 (Münich).

HENRY, E.—*Classification and Uses of Finger Prints*, 3rd Edition.

HERSCHEL, W.—*Nature*, 1880, xxiii., p. 76.

HERSCHEL, W.—*Origin of Finger Prints*, 1916 (Clarendon Press).

LOCARD, E.—*L'Identification des Recidivistes*, 1909.

LOCARD, E.—*La Poroscopie*, 1913.

MITCHELL, C. A.—*Science and the Criminal*, 1911 (London).

MITCHELL, C. A.—*The Detection of Finger Prints on Documents. Analyst*, 1920, xlv., p. 122.

OSBORN, A. S.—*Questioned Documents*, 1910 (Rochester, N.Y.).

PURKINJE, J. E.—*Commentatio de Examine physiol. Organi Visus et Systematis Cutanei* (Breslau), 1823.

STOCKIS.—*Annales Soc. Méd. Lég. Belge*, 1906, p. 7.

VUCETICH, J.—*Dactyloscopia Comparada*, 1904 (La Plata).

WELCKER, H.—*Arch. f. Anthropologie*, 1898, xxv., p. 29.

WILDER, H. W., AND WENTWORTH, B.—*Personal Identification*, 1918 (Boston, U.S.A.).

[1] *Flesh Foods*, pp. 33-45.

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