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Class No.....
पुस्तक सं.
Book No. .....
लेखक
Author Lucas, A. .....
शीर्षक
Title Forensic chemistry and scientific criminal .....

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FORENSIC CHEMISTRY AND SCIENTIFIC CRIMINAL INVESTIGATION

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BY

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LONDON
EDWARD ARNOLD & CO.

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First Published 1921
Second Edition 1931
Third Edition 1935
Reprinted 1937
Fourth Edition 1946
Reprinted 1946
Reprinted 1948

This book is produced in complete conformity with the authorised economy standards

Printed in Great Britain by
Butler & Tanner Ltd., Frome and London

PREFACE

ADVANTAGE has been taken of the demand for a new edition of Forensic Chemistry to bring it thoroughly up to date, and alterations and additions have been made throughout, and about 200 fresh references have been added.

During the recent war a large number of cases were submitted by the British Army in the Middle East (including the New Zealand, South African and Indian Forces), and the Royal Air Force in the Middle East, and a few by the United States Army and Air Force. These included 273 questioned document cases (chiefly handwriting, but also a few dealing with typewriting, with erasures and other alterations, and with charred documents); 37 shooting cases and a few miscellaneous cases, including erased inscriptions from rubber tyres and from metal.[1]

The most interesting points in connexion with these cases, except the shooting cases, have been incorporated in the appropriate places, but the shooting cases, many of which are very instructive, are given in greater detail and the important features of all of them are described.

A. LUCAS.

Cairo, 1945.

[1] The cases included are those received between December 1940 and December 1944.

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FORENSIC CHEMISTRY

CHAPTER I

INTRODUCTION

Definition of Forensic Chemistry. Forensic or legal chemistry may be defined as chemistry applied to the solution of certain problems that arise in connexion with the administration of justice. It is chemistry exercised in the service of the law.

Forensic Chemistry is often confused with Forensic Medicine, thus one writer states [1] that " One of the most valuable functions of the Medical Profession is the detection of poison, blood and other matters by chemical examination," and again, " Chemical analysis is in fact a special branch of medical jurisprudence . . ." This, however, is not so, and " the detection of poison, blood and other matters by chemical examination " is manifestly purely chemical and in no way medical, though it is convenient that the specialist undertaking such work should possess, as he often does, a medical as well as a chemical qualification so that he may combine the two subjects of Forensic Chemistry and Forensic Medicine.

Scope of Forensic Chemistry. The scope of forensic chemistry is very wide and the boundaries are ill-defined. Not only does it include the chemical side of criminal investigation, with which it is generally associated in the public mind, and to which it will be limited in the following pages, but it is concerned also with the analysis of any material the quality of which may give rise to legal proceedings. Forensic Chemistry, too, deals not only with purely chemical questions, such as the nature, composition and quality of materials as determined by analysis, and the examination of articles for the presence or absence of particular substances, such as poisons, but also with questions that are only partly chemical, for example the examination of blood stains, documents, counterfeit coins, fibres and textile fabrics, and the expert in forensic chemistry should be not only a capable analyst, but also an experienced microscopist and photographer.

Practice of Forensic Chemistry. The practice of forensic chemistry resolves itself naturally into three stages, namely (1) the reception of the article to be examined, (2) the examination, and (3) the communication of the results, all of which may be considered usefully in detail.

I. Reception of the Article. It is most important that whenever possible the expert should himself personally take such specimens as are

[1] W. R. Donough, *Principles of Circumstantial Evidence*, Calcutta, 1918, p. 131.

required for examination, except viscera to be tested for poisons, which are taken necessarily by the medical man who conducts the post-mortem examination. Unless this is done, something essential to the elucidation of the problem may be omitted, or the objects may be taken, handled or packed in such an unsatisfactory manner as to render them almost useless for purposes of investigation. Sometimes too it is necessary that the expert who examines an object should know not only the condition, but even the precise position in which it was found, and this can only be done when he is called in at the commencement of the enquiry and before anything is disturbed or removed. It is impossible to lay too much stress upon this point, for just as fingerprints or footprints may be obliterated and thus valuable evidence lost, so other clues may be destroyed or even misleading indications may be produced. Whenever possible therefore in all cases of criminal investigation in which a chemical expert is consulted, he should visit the scene of enquiry, make a detailed examination and take notes and measurements and also any specimens that may be required. This, however, is not always practicable and, even when practicable, the necessity is not always recognized and in the majority of cases the expert will not have the opportunity of taking specimens, which will generally have been done before he is called in and they will be handed or forwarded to him. If any object received is unsatisfactory by reason of its condition, its possible contamination with other objects, its small size, or its unsuitability for the purpose required, this should be pointed out at once and the necessary steps taken to procure additional specimens.

When taking over objects to be examined, a note should be made of the date and time of reception, from whom received, the number and kinds of objects, their identification marks and the manner in which they are packed.

When summoned to the scene of enquiry the expert should go fully prepared for all contingencies and should take with him everything that is likely to be required: a lens, a reading glass with a handle, a pen-knife, a few small round cardboard boxes for small objects and a measuring tape generally will be found useful, and a notebook of good quality and not too small a size and a pencil are indispensable. A camera is also frequently of service.

A neatly and accurately drawn sketch with all the important measurements shown will be found a great help in writing the report. This, however, should not be reproduced in the report, as unless drawn to scale it will be too inaccurate to be of practical value in Court. If a plan is necessary only one made by a trained surveyor should be used. In the case of a fire, explosion or similar occurrence, as much information as possible should be obtained regarding the exact previous condition of things, also an account of what was seen or heard at the time and the explanation that is given of the occurrence by those concerned. It should be remembered that generally

it is difficult or impossible to repeat a visit, and that, unless full details are obtained in the first instance the report will be incomplete and, in the absence of some small fact that has been omitted, it may be found impossible to express a definite opinion or to explain what otherwise might have been a very simple matter. Special care should be taken to make the notes not only full but neat and clear, since it may be necessary to produce them in Court, and if any mistakes are made these should not be erased but should be corrected in such a manner that the original entry can be read plainly. A careless superficial examination and any inaccuracy in recording the facts are inexcusable. When the expert himself takes the samples, full particulars should be written on each at the time and exact notes made of the place, date and circumstances.

As no conclusions of value can be formed without a knowledge of all the facts, no opinion whatever should be given until the articles have been examined and the matter carefully considered.

As soon as practicable after an article has been received it should be registered, and the register should show the date of receipt, from whom received, the nature of the article and details of all numbers or other distinguishing marks.

At this stage the package should not as a rule be opened, but, whenever it is opened, this should be done by the expert himself.

As a rule it is sufficient to keep one general register in which all articles are entered in order of date, each being given a special number, these being consecutive in any one year. The serial number of the article and the year should be marked on the outside of the package. If, however, a large number of articles of any one kind are being received constantly it will be found convenient to have more than one register, though rarely, if ever, will it be necessary to have more than two, one for the class of articles that predominates and a second for miscellaneous cases. As the reports are frequently too lengthy to be transcribed conveniently into a register, it is generally best to keep typed copies in separate files according to the nature of the case, though a brief summary in the register will be found useful. The register also should show the date of the report and the number and page of the laboratory workbook in which the original facts and figures were entered at the time the article was examined, so that they may be found quickly when required for reference.

In addition to the general register or registers, however, a series of abstracts, one for each kind of article, in which the results of the analyses are summarized, will be found useful. These are for quick reference to the details of the cases. In the Poisons Abstract, for example, there should be a separate page for each kind of poison, and the cases should be entered in numerical order with details showing the nature and weight of the article

analysed and the amount and percentage of poison present. In the Counterfeit Coin Abstract, such particulars as the denomination of the coin, the year, weight, specific gravity, composition and whether struck or cast, should be given in tabular form. Thus the number of cases of any particular kind and the details of each case may be seen at a glance.

Articles are frequently very badly packed, very inadequately marked, and insufficiently secured and sealed or sometimes even not sealed at all.[1] This is not the fault of the expert but, by drawing attention to it each time it occurs, improvements in this respect may be brought about. The commonest faults are the use of wet or dirty bottles ; dirty corks ; insufficient protection of glass vessels during transit ; the use of thin cardboard boxes which cannot be closed securely and which break easily or become forced out of shape, and so allow the contents to escape ; the use of ordinary correspondence envelopes from which finely powdered materials always leak ; the packing of several articles in one parcel in such a manner that contamination of one with another is almost inevitable, and the use of sealing wax on the corks of bottles containing alcoholic liquors or other liquids in which sealing wax is soluble. Many articles too are received without sufficient marks of identity or else bear such marks only on the outside wrapper, which has to be removed. It does not seem to be recognized sufficiently that ordinary gummed labels do not adhere well to tins or to painted or glazed surfaces, with the result that such labels frequently come off and the articles are left without any means of identification. For small specimens of dry material the round cardboard boxes, that are sold in nests of different sizes, will be found useful. Oblong envelopes with the opening at the end are satisfactory, except for powders, and such envelopes are made in all sizes specially for holding samples, and many have ingenious methods of fastening. Explosives, acids and other dangerous materials are frequently packed in a very unsafe manner. Thus gelignite of uncertain age and stability has been handed to me for examination merely wrapped in a handkerchief ; a potassium chlorate explosive was forwarded in a glass-stoppered bottle with some of the material adhering to the neck of the bottle and liable to explode on any movement of the stopper ; a solution of phosphorus in carbon disulphide, which is spontaneously inflammable when the solvent evaporates, was forwarded in a bottle having a loose-fitting stopper and was packed very insecurely, and it is a common experience to find strong acids and alkalies put into bottles provided with corks instead of glass stoppers, with the result that the corks become corroded and the liquid escapes. Instructions regarding packing will be found in many of the chapters dealing with special subjects.

[1] See F. G. Tryhorn, " The Packing of Exhibits," *Police Journal*, 8 (1935), pp. 19-26. Also F. Bamford, *Poisons : Their Isolation and Identification*, 1940, pp. 1-4.

II. The Examination. The first step in the examination of an article is to scrutinize it carefully and to write down in the laboratory notebook [1] a full description of its appearance. The outside of the package, the manner in which it is secured and particulars of the sealings, if any, should be described first. Then the package should be opened and any inner wrappings or packages described, and finally a detailed description of the appearance of the article itself should be given. This will be found very helpful, since before an article can be described it must be examined carefully and minutely, and definite conclusions must be arrived at on such points as colour, shape, size and other physical characteristics that otherwise might be left vague and inconclusive.

The serial number, originally marked on the outside wrapper, should now be put on the article itself, if possible, or, if not possible, then on the innermost package. When, however, the article consists of a written or printed document, this as a rule should not be numbered or marked in any way, as by inadvertently covering up something of importance the value of the document as evidence may be impaired seriously, and what is, or is not, of importance frequently cannot be recognized until the document is examined critically. Occasionally, when there are a number of different documents that must be referred to separately in the report, it may be necessary to mark them, but this should be done carefully and generally in one corner. Frequently, however, documents will bear a distinguishing mark or number when received. The practice adopted by some experts of placing their name or initials on all documents as a means of identification is unnecessary. If a document has been examined carefully and described it can always be identified again. In the case of some articles, particularly those of metal, marking is not always easy, but this should be done whenever possible. Coins, which easily may be confused, should always have a small distinguishing mark or number scratched on them. Frequently considerable trouble is caused during a trial, in which there are a large number of different exhibits, by the confusion of similar articles or by mistakes in identification due to insufficient or unsatisfactory marking.

The original package should be opened in such a manner that if possible the sealings remain intact, since sometimes questions concerning these arise in Court during a trial and further examination of them may be necessary. For the same reason all wrappers should be kept. In one case in Egypt counsel for the defence commented very strongly on the fact that the envelopes, in which certain documents seized by the police had been enclosed, could not be produced, thus rendering it impossible to prove whether

[1] The notebook should be of good quality, with ruled paper and a stiff back, which should not be of the glazed black material so often used, but of something on which it is possible to write the consecutive number of the book and the date. All entries in this book should be in ink.

or not they had been fastened and sealed in a satisfactory manner or had been left in such a condition that they might have been opened and the contents tampered with. Before opening any package it should be seen that the table on which this is done is clean and unencumbered with other objects.

From the time the package is opened until the examination is finished and until the object is sealed up again it should never leave the personal custody of the expert and should not be left about the laboratory or be exposed unnecessarily, but when not required it should be kept in a locked room or cupboard to which the expert alone has access. In special cases this room or cupboard should be not only locked, but sealed every time the expert leaves the premises, since if the identity or integrity of an object is challenged and cannot be proved, all work on it becomes useless. In poisoning cases, except routine ones where it is impracticable, no one but the analyst and persons connected with the case in the analyst's presence should be allowed to enter the room and no poisons, other than the reagents required, should be permitted in the room, which should be cleaned specially before the work is begun.

The second step in the examination, if an article requires chemical analysis, is as a rule to weigh or measure it, after which, if possible, it is divided into several portions, one being kept in its original condition for further reference or for production in Court. All weights and measures should be entered directly in ink in the laboratory notebook at the time they are determined. When, however, an object has become a Court exhibit written permission from the Court is necessary before its condition may be changed in any way and without such permission only an examination with the naked eye or with a lens or microscope or such simple determinations as weighing or measuring should be made.

The third step is the chemical analysis, microscopical or other examination or physical testing, whichever may be indicated. It is not proposed to describe methods that are known to every analyst and that may be found in the ordinary textbooks, since before a chemist specializes in legal cases naturally he will have had experience in general analysis, and he will be familiar therefore with the usual methods and processes and will know also where to find the description of additional methods should he require them. For matters that are outside the range of an analyst's ordinary work special books must be consulted and the names of a few such books will be given in connexion with the various subjects dealt with. Certain types of cases, however, such for example as those concerning clothing, questioned documents, explosives, explosions, fires, robbery, stains and marks, will present different aspects and new features every time, and the methods of dealing with them can be learned only by practical experience. In the following chapters the methods adopted in special cases will be described.

Whenever a chemical analysis is made care should be taken that the apparatus and vessels used are clean, that the reagents are pure and that the analysis is conducted in such surroundings and in such a manner that contamination or loss is impossible. It is not merely sufficient for the expert himself to be satisfied that all these things are as they should be, but he must be in a position to convince others. For example, he may feel certain that the reagents employed are pure, but he cannot definitely refute a suggestion or statement to the contrary unless he has the positive evidence that can be obtained only by having tested them. During the Maybrick trial one of the witnesses, who had made a preliminary test for arsenic, when asked about the purity of the copper and hydrochloric acid employed, said with regard to the former, " I do not know whether the copper was absolutely pure but I have a very strong impression that it was pure," and with regard to the latter, that he had bought it from " the chemist." [1] Blank or control experiments should be made whenever possible. At every stage full notes should be made in ink in the laboratory notebook. Pencil notes and scraps of paper should never be used.

All residues, filtrates, washings and remainders should be preserved until the analyses are finished, when those not required may be rejected, but any important ingredient separated in the course of an analysis should be preserved for production in Court.

After the examination or analysis is finished, the article or residue should be sealed securely, and either kept for production in Court or handed over to the proper authorities. It is preferable whenever possible that the expert should retain the articles he has examined and should himself produce them in Court, as few people realize the importance of the proper care of exhibits.

The expert will generally have some help in his work but he must conduct personally all the important operations and should see and verify everything else that is done and form his own conclusions independently of the opinion of others, since it is he who is responsible and it is he who will make and sign the report and give evidence in Court, and he must therefore be in a position to describe both the article itself and the method of its examination and to justify the conclusions.

Some of the precautions mentioned may possibly appear trivial and unnecessary, but experience proves that none of them can be dispensed with safely, and the neglect of any one may discount seriously the value of the most careful analysis or even invalidate it altogether. Thus, for instance, the authenticity of an article may be challenged and it then becomes necessary for the expert to prove, not only that it had never been out of his custody since he first received it until the examination was finished, but also that it is impossible it could have been tampered with in any way or that anything

[1] H. B. Irving, *Trial of Mrs Maybrick*, 1912, pp. 105, 106.

could have been added or abstracted. It should not be forgotten too that the chemico-legal expert occupies a very different position from that of the ordinary analyst in that everything he does is liable to be subjected to the strictest scrutiny and adverse criticism, and his work is either done on oath or the results must be sworn to. Moreover, where the liberty or life of another is concerned it is impossible to be too careful.

In the practice of forensic chemistry there are six golden rules which should never be forgotten. These are :

1. Go slowly : good work cannot be hurried, therefore take all the time necessary to make the case complete, no matter how urgent it may appear or how pressing others may be for the result ; it is generally possible to adjourn a case if the work cannot be finished in time.[1]

2. Be thorough : make a careful and minute examination of everything and do not be satisfied with a qualitative analysis if a quantitative one be possible ; it always pays to do too much rather than too little and it is difficult to foresee what will or will not be required in Court.

3. Take notes : keep a full, neat and clear record of everything seen and done.

4. Consult others : many cases will lead the expert into paths with which he is not familiar, and when this happens he should consult those who are most likely to know. Unless an expert knows his subject thoroughly, or unless he consults others, he may go astray seriously ; thus a doctor, who found salt in an Egyptian mummy, reported it to be that of a person who had been drowned in salt water, apparently in ignorance of the readily ascertained facts that crude natron, which contains a large proportion of salt, and at a later date, salt itself, were commonly used in connexion with mummification. The chemist too who thought that the ancient Egyptians used quicklime as a body preservative, because he found a small amount of calcium carbonate in a mummy, was evidently unaware of the extent to which limestone and limestone dust occur in Egypt ; that burial in tombs cut in the limestone rock was very common and that the natron used in the desiccation of the body might have contained calcium carbonate. Another expert, who had not made himself familiar with the methods of using liquid fuel under a boiler, but who evidently had heard of the use of compressed air in that connexion, thought that this was forced into the oil in the feed tank.

5. Use imagination : this is somewhat hazardous advice, since an expert with a vivid and uncontrolled imagination is a most dangerous person ; a disciplined imagination, however, which enables inferences and deductions

[1] Sir W. H. Willcox, with reference to the Crippen case, states that " It took no less than a month to get out the hyoscine." (" The Influence of Chemical Research on Medicine and Forensic Medicine," *Institute of Chemistry Lecture*, p. 14.)

(to be verified or discarded at a later stage) to be made from slender and incomplete premises is often very useful. The imagination, however, must be kept well in hand in writing the report and the expert should remember that what to him may be merely a helpful working hypothesis is liable to be taken by others for more than its true worth and to be adopted by them as a final explanation.

6. Avoid complicated theories: the simplest explanation is usually the right one. The interpretation of results is often the most difficult part of the expert's work, and a precise knowledge of miscellaneous facts, a sound judgment, good reasoning powers and what has already been described as " a disciplined imagination " are all essential to success.

III. **Communication of the Results.** The results of the work carried out will be communicated generally in the form of a written report, to be supplemented at a later date by oral evidence. Both therefore will be considered.

The written report should commence with an enumeration of the articles received for examination, the date of receipt and from whom received, and should state how they were packed and whether they were fastened securely or not and whether sealed, and if so a description of the sealings should be added. Then a brief but sufficient record of all the significant facts noted during the examination of the article should be given, followed by a summary of the conclusions drawn from the observed facts and from these alone, the conclusions, however, being kept quite distinct from the facts and the whole being expressed in plain and non-technical language. The conclusions should be stated definitely and without ambiguity, vague and inconclusive opinions being useless. This, however, does not mean that there should be dogmatism on insufficient data and it is necessary sometimes to state that the facts are so few or so obscure that no definite conclusions are possible.

All opinions should be supported by the evidence on which they are based, that is to say every statement made should be proved and unless a point can be proved to the satisfaction of others generally it will be found to be worthless.

In ordinary gravimetric or volumetric analysis it is neither necessary nor wise to report the results to more than one decimal place, as although the weights, measurements and calculations will probably be carried out to two or even to four decimal places, yet the errors inherent in the method, apparatus and manipulation are such that anything beyond the second decimal is doubtful, and even the second decimal is liable to be wrong. In special cases, however, such as the analysis of poisons, the results must be given frequently to tenths or even hundredths of a milligram. Thus in the Seddon trial quantities of metallic arsenic varying from one-thirtieth to

one-three-hundredth part of a milligram were obtained by the analyst from the various samples.[1]

It is not, as a rule, necessary to mention how an analysis or examination has been conducted and therefore, whenever possible, all references to methods should be omitted, as their inclusion only lengthens and complicates the report, though sometimes it is useful to state that the analysis has been conducted by well-known methods, which are named. The one endeavour in writing the report should be to make it as concise and clear as possible. Utility, however, should not be sacrificed to brevity, and the report should be sufficiently full and explanatory to meet any adverse criticism it may encounter, containing within itself the replies to any arguments likely to be directed against the conclusions reached, since the expert may be unable subsequently to supplement his report by further details or explanations.

If photomicrographs or photographic enlargements of objects have been made, copies of these should be attached to the report, and it should be stated clearly on the photographs what they represent, and any special points illustrated should be indicated.

After drafting a report and before it is copied finally and forwarded it will be found a useful check on the correctness of the conclusions for the expert to put himself mentally in the place of the counsel for the opposite side and to scrutinize the report carefully from that point of view, more particularly as to whether the data are sufficient to justify the conclusions, and whether or not explanations other than those given may not agree equally well with the facts.

So far as oral evidence is concerned, the principal requirement is that the expert should have a thorough knowledge of his subject and of the collateral matters relating to it. Since the evidence may be given weeks or even months after the work has been done and the report written, it is not only permissible but necessary that the expert should refresh his memory by reference to his laboratory notebook before presenting himself in Court, and he should also have the book and a copy of his report with him in Court for further reference if required. It is not sufficient that these should be consulted for a few minutes immediately before going to the Court or while waiting to be called, but they should be studied well beforehand. A witness with a bad memory, or one who has not taken the trouble to refresh his mind with the facts of the case, presents a very poor spectacle in the witness box. It should be remembered, however, that no notes, except those made at the time the work was done or as soon after as practicable, are allowed in Court and nothing written subsequently is permitted to be used. The expert must anticipate and prepare himself to answer likely questions

[1] F. Young, *Trial of the Seddons*, 1914, pp. 120, 123.

having reference to the case [1] and should have at his fingers' ends all the details of the methods of analysis or examination employed and should be prepared to state the degree of accuracy attained. He should also know the weaknesses, if any, inherent in the methods used and be ready to meet adverse criticism directed against them. All answers to questions and all opinions should be definite and free from ambiguity and should be given in as simple language as possible, and, what is of the utmost importance, they should be concise, brevity being the essence of good evidence. Lengthy explanations weaken the evidence and may raise points that can be used by the opposite side to cast doubts upon it. The expert should be prepared also to say what practice he has had in the particular kind of examination under consideration, how many years his experience covers and approximately how many cases of a similar nature he has investigated.

Should it be necessary to employ any term susceptible of more than one meaning, such for example as " arsenic " when either the oxide or the sulphide might be meant, the sense in which the term is used should be made clear. Some confusion seems to have arisen during the trial of Mrs Maybrick owing to the neglect of this precaution, and the amount of arsenic found on analysis was referred to by the witnesses sometimes as oxide, sometimes as sulphide and sometimes merely as arsenic without any indication what compound was meant. In the Palmer trial the term " antimony " was used in the same loose manner. If the terms " small amount " or " trace " are employed, the expert should be prepared to state approximately the quantity meant.

As an indication of the kind of questions that may be asked in cross examination, for which preparation should be made, my own experience in a few cases may be mentioned: when giving evidence in cases of counterfeit coining I have been called upon to state how genuine coins are made, to explain the difference between cast iron, wrought iron and steel and to justify my statement that certain instruments were made of steel, to give the approximate pressure required to impress the designs of some steel dies upon a given alloy and to say whether a certain press, that the prosecution had contended was part of a counterfeit-coining plant and that the defence explained had been employed for making small tiles, could be used for making tiles or not, and whether the accused person's description of the materials and method employed for making tiles was correct. In connexion with various bomb outrages I have been asked to estimate the amount of explosive employed, to give the relative strength of different explosives, the radius of a particular explosion, and the probable distance that a bomb had exploded from an object that had been hit, and to define

[1] An excellent training for the witness box may be obtained by reading the published accounts of trials of similar cases to those in which the expert specializes.

explosion and detonation and to explain the difference between them. In handwriting cases it is not unusual for the expert to be asked to express an opinion upon signatures or writing handed to him in the witness box. This he should decline to do, even though the answer to the question seems obvious, unless he is given an opportunity of making a proper examination. There is generally some " catch " in such questions. He may be asked, too, especially in handwriting cases, whether he is infallible, as has happened to me several times. The reply was, " No, but I believe I am correct in this instance." In cross examination the expert should admit freely and without hesitation anything that is true, even though he knows it will be used to discount the value of his own evidence. He may, however, qualify such admission by any necessary explanation.

" Provided the witness is *in fact* skilled in the comparison of handwriting, it is immaterial that he is not a professional expert and immaterial how he acquired his skill. *R. v. Silverlock*, L. R. (1894), 2 Q. B. 766." [1]

Sometimes an object, such as a detail of the design of a counterfeit coin, a defect in a counterfeit coin, a characteristic in a handwriting or an alteration or erasure in a document, about which evidence is being given in Court, is so small that it cannot be seen clearly, or even cannot be seen at all, unless it is magnified. No attempt, however, should be made to show the object to the judge or jury through a microscope, or even through any sort of small lens, since these instruments are only confusing to persons not accustomed to their use. In such circumstances the expert should be prepared with an enlarged photograph of the object in question, though sometimes a large reading glass with a handle may be found useful, as this can be understood and managed by most people. In the Maybrick trial the judge, after endeavouring vainly to see a deposit of oxide of arsenic on the sides of a tube by means of a lens, remarked of the latter that " it was very difficult to manage." [2] In the Browne and Kennedy trial, however, the jury were given a microscope to enable them to examine certain markings on a cartridge case.[3]

A final word of caution may be given, namely, that the expert should avoid allowing his interest in a case or his belief in the correctness of his own conclusions to make him an advocate or partisan ; he appears in order to present any facts he may have discovered, to interpret these and other facts and to help the Court with opinions, and his evidence should be given without bias to either side.

Reference to Expert. It is rarely satisfactory for an examination to be undertaken jointly by several experts, especially when they are of different nationalities, as often happens in Egypt, since the less qualified or less

[1] *Manual of Military Law*, 1929, Reprinted 1939, p. 89.
[2] H. B. Irving, *Trial of Mrs Maybrick*, 1912, p. 136.
[3] W. T. Shore, *Trial of Browne and Kennedy*, 1930, p. 109.

experienced member handicaps the others ; it also adds to the time required and not infrequently ends in a compromise of opinion. That various experts should be consulted on different aspects of a problem is reasonable and often necessary, but each should make his investigation and report independently of the others.

When an official expert is available, it is important that all cases of the particular kind in which he specializes, even the most obvious, should be referred to him. Sometimes there is a tendency to refrain from troubling the expert with cases that appear simple, or in which, either there is not sufficient evidence to go to trial, or ample evidence to secure conviction without his help, but all cases should be submitted, since information derived from one may be invaluable in another, particularly during cross examination. Also if there is any connexion between different cases, as often happens with forged banknotes and counterfeit coins, this may be missed unless all pass through the same hands. The expert, on his side, should welcome all cases, even the most trivial, since the wider his experience becomes, the more valuable are his services. As an example of the utility of the expert having first-hand experience, it may be mentioned that during a trial in connexion with a bomb outrage it was possible for me to refute the theory put forward by the defence that the bomb was only a kind of firework intended to frighten and not to hurt, by my being able to state from personal knowledge that a similar bomb had killed one person, injured three others and caused considerable damage to a motor car and to the walls on both sides of the street in which it had exploded. In a subsequent and different trial these facts were again helpful, as also the description of the damage caused by a further bomb.

Conclusion. In conclusion it is desired to emphasize the fact of the great assistance that the chemist can render in the administration of justice. This is generally conceded with regard to all matters pertaining to the composition of materials or to their value as determined by analysis, but it is not recognized sufficiently in connexion with criminal investigation, except in cases of poisoning, when the chemist is acknowledged to be indispensable.

The chemist is specially trained in observation and deduction ; he learns to enquire closely into the nature and meaning of things ; as a result of experience he becomes very sceptical of outward appearances ; if he practises as an analyst he is brought into intimate contact with a great variety of different materials, of all of which he must know the composition and properties, and he deals habitually with traces of substances and weighs and measures them, all of which qualifications peculiarly fit him to act as a scientific expert in criminal investigation. Observation, deduction, an

enquiring turn of mind, a scepticism of appearances, a knowledge of the composition, properties and uses of materials and the ability to see and examine traces are all essential for this work, and it may be stated confidently that if criminal investigation is to keep abreast of the times it must be made more scientific and chemical analysis and microscopy must be used more frequently; in fact, the criminal is becoming so scientific, not only in his work, but also in the means he adopts to escape detection, that a scientist is needed to cope with him, that is to say, a scientist must be set to catch a scientist.

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CHAPTER II

BLOOD STAINS

As an aid in the detection of crime, the value of testing stains that look like blood is well known, and it is possible to determine, not only whether such stains are blood or not, but also whether they are human blood and to which of the four principal blood groups they belong, and, if not human blood, to ascertain what kind of blood they are.

The testing of blood is largely chemical, more particularly since the antisera required for the biochemical test need no longer be prepared by the expert but may be purchased ready for use, and there is no doubt that the chemist, by reason of his training and experience in manipulation and his skill in testing and in general laboratory practice, is well qualified to undertake this work. It may be mentioned, too, that the " detection of blood stains " is among the subjects required to be known by all candidates presenting themselves for the examination for the Fellowship of the Royal Institute of Chemistry. Blood testing in legal cases, however, should only be undertaken by those having considerable experience of such work, as issues of life and death frequently depend upon the results.

Articles sent to be examined for blood stains may include clothing, weapons, tools, wood (walking sticks, clubs, parts of furniture, doors or floors), stones, earth and plaster. Blood stains when recent are usually red and older stains chocolate-brown, but the colour varies with the nature and colour of the material on which the stain occurs and also depends upon whether attempts have been made to remove it by washing. On damp fabrics blood stains sometimes fade quickly and assume a faint greenish or bleached appearance. Stains having a similar appearance to those of blood may be due to vegetable juices, fruit juices, rust, paint, coffee, sealing wax or dye.

Search for and Preservation of Blood-stained Articles. This is a matter for the police, or other investigating authority, but the search for blood-stained objects at the scene of the crime or on the person or in the house of a suspect cannot be undertaken too carefully. Unimportant as a small blood stain may appear among a number of larger stains, the determination of its origin may have great significance if, as sometimes happens, blood stains of more than one origin occur together, as may be the case, for example, if a dog is killed in defence of its master, when mixed human and dog blood might be found. In a case of a bomb outrage in which the perpetrator was badly wounded and subsequently died, there

was a trail of blood in the street, specimens of which I took for examination. In addition to the main trail, however, there was a second trail, that was also sampled, as it was thought that there might have been an accomplice who also had been wounded. The two lots of blood were kept separate and when examined by the precipitin test it was found that the first was human blood and the second fowl blood, the latter being due almost certainly to a fowl having been killed in the street, a very common practice in Egypt. If the two lots of blood had been mixed, considerable confusion might have resulted.

When searching for blood stains attention should be directed not only to clothing and weapons, but the finger nails, boots and linings of the pockets of the suspected person also should be examined. If too much time has not elapsed since the occurrence of the crime, the possible movements of the suspected person should be considered and search made for anything that might have been used for wiping or washing stains from his clothing or person, or for any means likely to have been adopted for getting rid of blood-stained objects. Thus recently washed clothing or rags found hidden away, partially burnt material and fresh ashes should always be submitted for examination. It cannot be emphasized too strongly that as liberal a supply of blood-stained or suspicious objects as possible should be collected regardless of the subsequent work entailed in examining them. Blood stains that have been washed so completely out of a fabric as to be invisible by ordinary light, even when the material is photographed, often show clearly when exposed to the ultra-violet rays [1] or when photographed with infra-red sensitive plates.[2] This, however, is no proof of the nature of the stains, which must be determined in the usual manner, but it indicates where tests may be applied usefully.

When searching the scene of a crime for blood stains particular note should be taken (and if possible a photograph made) of the position, size and shape of any stains found, as these may afford a guide to the direction in which the blood was falling or spurting or in which the blood-stained object was moving or was being carried. Spraying from a cut artery causes extremely small stains which, except for the fact that there are a great number very close together, possess an appearance closely resembling flea marks.

In cases of stabbing, the blade of the knife, while being withdrawn, is wiped by the edges of the wound, and after drying only a thin film of a faint brown colour may remain. On the other hand blood often is found at the junction of the blade and the handle of a weapon as it may run down where

[1] F. W. Martin, " Ultra-Violet Rays in Criminal Investigation," *The Police Journal*, 7 (1934), pp. 431–2.

[2] F. W. Martin, " Infra-Red Rays in Criminal Investigation," *British Medical Journal*, 1933, pp. 1025–6 ; *Analyst*, 58 (1933), pp. 644–5.

the tang fits into the handle, a point usually overlooked by criminals when cleaning weapons after a crime. On such articles, the blood when examined with a lens often looks like fresh red varnish. Wooden handles of tools too that have split or on which there are surface cracks absorb blood into the cracks in a manner that even sandpaper fails to remove, and weapons and tools, even though cleaned and superficially not showing any traces of blood, should always be sent for examination.

Blood Stains on Immovable Objects. As it is much easier and more satisfactory to examine blood stains in the laboratory than elsewhere, the stained portion of any large immovable object should be cut out or dissected away whenever possible. For example, stains on wooden flooring, doors, doorposts or furniture should be sawn out if the stain is sufficiently adherent to withstand the vibration ; bricks or stones should be dislodged carefully from floors and walls, and plaster should be cut away in large pieces. Sometimes, however, the best manner of dealing with blood stains is to scrape them off, and when this is done the various groups of stains should be collected in numbered packets of *soft* paper, a note being taken of their position and shape. It should be remembered that blood stains of different origin may be present and consequently only those stains close together or parts of a single splash or smear should be mixed. As the blood serum on which the biochemical test depends soaks into porous matter, it is advisable to scrape off at least 0·5 mm. depth of substance below the stain, as this may be richer in serum than the superficial clot, but as this material may contain substances that might nullify the serum test, it should not be mixed with the purer superficial layer, but should be packed separately. Scrapings are collected easily by means of a small scoop made by bending a piece of clean, bright tin and sweeping the blood into it with a small new camel-hair paintbrush, which, however, should never be used again for blood work.

Blood Stains on the Person or on Animals. The method of removing blood stains for testing purposes from the person or from animals that would occur probably to most people, not having experience in the matter, as being the best, would be to rub the place with a small swab of wet cotton wool, but if this be done the subsequent tests are very troublesome, as the blood is so disseminated in the swab that it may be impossible to find any portion with a sufficient concentration to respond to the tests. A large volume of saline, too, must be used for extraction, with the consequent danger of a negative test through too much dilution, though a dilute solution may be concentrated if necessary in a vacuum desiccator. The best method of removing the blood in such cases is to moisten a clean piece of blotting paper or white fabric, one or two centimetres square, with physiological

saline solution (0·9 per cent. sodium chloride in water) and allow this to lie on the stain until the paper or cloth is stained. This should then be dried in a gentle draught (never by heat) before being packed up and despatched to the laboratory. In this way a concentrated stain on a small amount of material is obtained to which the tests are easily applied.

Blood Stains on Damp Objects. Damp objects such as boots, mud and recently washed clothing must be dried before being packed up, or a growth of mould, bacterial action or putrefaction of the blood matter may set in and hinder or possibly even nullify the serum test. The drying must be carried out in a gentle draught or in a warm room and never by artificial heat.

Blood Stains on Friable Objects. Stains on friable objects such as plaster, dried mud or dry leaves require special packing. Unless this is done, the shaking in transit causes such material to crumble, and blood that originally was visible easily on the surface is almost hopelessly lost in a mass of powder on arrival at the laboratory, and though examination with a lens may possibly result in the finding of small stained fragments of material, considerable trouble is avoided if special means of packing are adopted. Embedding in a mass of plasticine, stained side uppermost, packing in a small cardboard box with dry cotton wool and then in a larger box, or scraping off the stain are recommended.

Preservatives. In no case should any preservative whatever be added to or packed with blood stains, and only clean paper or dry cotton wool should be allowed to come into contact with them. Care should be taken that gum, candle grease or sealing wax do not contaminate the stains, while the package is being fastened or sealed. Many hours are sometimes wasted by the expert in a fruitless attempt to obtain a test for blood from what eventually proves to be red sealing wax.

Examination of Blood Stains.

The examination of blood stains is divided into three stages, namely :

(1) A preliminary test. This is a quick, easy method of deciding whether a stain is likely to be blood or not. At present there is no simple chemical test known that is absolute proof of the presence of blood, but there are several tests by means of which a stain may be excluded as not being blood.

(2) Confirmatory tests. These may be divided into :

(*a*) Microscopic examination for corpuscles.

(*b*) Micro-chemical test : production of hæmin crystals.

(*c*) Observation with the microspectroscope of a characteristic absorption spectrum of some form of hæmoglobin, usually that of hæmochromogen (reduced hæmatin).

(3) Determination of the origin of the blood by means of the biochemical or precipitin antiserum test.

These tests will be considered in detail.

Preliminary Test for Blood. This consists in observing a colour change in a chemical reagent when applied to a part of the suspected stain or scraping. At one time guaiacum was employed, but although the guaiacum test has been improved by careful technique, it has been superseded by the use of other substances, among which benzidine (paradiamino-diphenyl) and phenolphthal*in* [1] [2] may be mentioned, the former being recommended as the more satisfactory of the two ; also it is readily obtained in the pure state and it may be applied directly to the stain without extraction. In the presence of benzidine and hydrogen peroxide the hæmoglobin of the blood produces a deep blue colour.

An excellent and convenient method of obtaining hydrogen peroxide is furnished by sodium perborate, which gives off hydrogen peroxide when dissolved in acetic acid.

The sensitiveness of the benzidine solution depends upon the concentration ; if this is weak the colour produced, instead of being blue, may be greenish. Excess of both acid and hydrogen peroxide should be avoided. The solution recommended is made as follows : Dissolve 0·2 gram of dry sodium perborate in 1 c.c. of distilled water and 10 c.c. of glacial acetic acid. To this add 1 c.c. of a 10 per cent. solution of benzidine in glacial acetic acid made by dissolving 0·2 gram of benzidine in 2 c.c. of glacial acetic acid. If sodium perborate is not available, 2 c.c. of 6 per cent. hydrogen peroxide is substituted.[3] [4] The mixture has a pale straw or brown tint that darkens on standing, and if the reagents are impure, it will rapidly turn blue. It should be prepared immediately before use, as it

[1] The colourless reduction product obtained by acting upon phenolphthal*ein* with zinc dust in alkaline solution. In the presence of blood re-oxidation takes place and a pink colour is produced.

[2] (*a*) J. Glaister, " The Kastle-Meyer Test for the Detection of Blood," *The British Medical Journal*, 1926, **1**, pp. 650–2, 808 ; (*b*) D. Kerr, *op. cit.*, p. 721 ; (*c*) R. O. Girdwood, *op. cit.*, p. 808 ; (*d*) J. A. Gardner and G. A. Buckmaster, *Allen's Commercial Organic Analysis*, **10** (1933), pp. 34–5.

[3] Willcox recommends a saturated solution of benzidine in glacial acetic acid diluted with four times its volume of 10 per cent. hydrogen peroxide solution. *Analyst*, **38** (1913), p. 190.

[4] The ordinary commercial form of hydrogen peroxide is a water solution, which is sold in different strengths, usually 10, 20 and 40 volumes (about 3, 6 and 12 per cent. respectively), the volumes representing the yield of oxygen when decomposed. Before use, hydrogen peroxide should be tested with litmus paper and, if acid, as is often the case, it should be neutralized by the careful addition of a small quantity of a dilute solution of ammonia. This not only makes the reagent safer in use, but also produces a more satisfactory liberation of hydrogen.

will only keep for a few hours, and pure recrystallized benzidine should be used. The test is carried out as follows :

A double layer of white filter paper of good quality is spread on a porcelain tile and a minute fragment of dried blood or blood-stained fabric laid upon it. If the blood-stained object cannot be scraped or cut, a small white filter paper just damped (not soaked) with physiological saline solution (0·9 per cent. sodium chloride in water) should be pressed on the stain, a part of which will be transferred to the filter paper, where it can be tested. In no circumstances should the test be made directly on the stained object. A drop of the benzidine solution is added by means of a pipette. A blue or bluish-green coloration, radiating out in streaks on the filter paper, is produced instantaneously if blood is present. Moistening the material with pyridine before the addition of the benzidine solution promotes rapidity of action. Many substances, including soiled earth, manure and excrement, will give a similar blue coloration and even filter paper will do this after some time, but when blood is present the action is practically instantaneous. Stains that do not react within five seconds after being moistened well with pyridine can be disregarded unless the blood has become insoluble. The sensitiveness of the reagent towards old stains is increased by the addition of more perborate or more hydrogen peroxide, while the depth of colour is increased by adding more benzidine. Prepared as described this reagent is extremely sensitive. An instantaneous reaction has been obtained by Colles [1] with blood stains that had been kept in a sub-tropical laboratory for eighteen years : blood boiled for an hour and kept for thirteen years responded readily : blood stains on rusty iron kept for four years reacted within five seconds. It is almost impossible to wash out blood from cloth so that the fabric will fail to give a blue colour with the reagent.

As the value of the test lies in proving that a stain is not due to blood, it is important that the solution used should be sensitive, and to make sure of this, it is advisable to test it before use against blood stains that have been aged artificially, which may be done by heating blood on cloth, paper or iron in an air oven to 130° C. for some hours. The solution, however, should not be made too sensitive, or much unnecessary work will be entailed in trying to confirm stains that are not due to blood.

Negative Results. A brown stain apparently of recent origin that does not react within five seconds usually can be asserted not to be due to blood, though before definitely concluding that a stain is not blood, the circumstances of the case must be considered. In the course of many thousands of tests carried out by Colles in Egypt, only one group of stains, and these were

[1] Mr W. M. Colles, B.Sc., formerly of the Ministry of Justice, Cairo, and for many years in charge of all blood testing and toxicological work for the Egyptian Government.

old, faint, iron-grey coloured stains on the inner lining of a pocket, that were afterwards proved to be blood stains, failed to give the reaction within the specified time. In the case of greasy, washed, grey, old-looking stains, especially if the garment or article appears to have been cleaned or scraped recently, a supersensitive solution of benzidine should be prepared and the test repeated, moistening with pyridine, and watching with a lens for any colour change. It is extremely doubtful, however, if a stain that reacts sluggishly with benzidine will ever give the confirmatory tests for hæmoglobin, as the former test far exceeds the latter in delicacy.

In Egypt garments seized from peasants suspected of murder frequently exhibit stains that resemble blood in appearance to an extraordinary degree, but that are stated to be derived from such sources as cotton stalks, the date palm, sugar cane or maize. A great many cases in which the benzidine test was doubtful have been examined exhaustively for hæmoglobin by the spectroscope and by Beam's modification of the hæmin test and in no case has the presence of blood ever been proved after a negative benzidine reaction. In Palestine it has been found that the juice of olives will often produce stains having a strong resemblance to blood.[1]

Articles to be Examined for Blood Stains.

(*a*) CLOTHING. Clothes should be supported on a line by wooden pegs or on a tailor's dummy in such a way that they can be examined readily both inside and outside. Failing any prominent stains, the examination should commence with the cuffs and sleeves and the whole garment should be inspected systematically on both sides. Minute portions should be cut out of each stain [2] with curved scissors, the pieces being held by forceps, and these pieces should be tested in the manner described. Stains positive to benzidine should be marked with small flag labels, safety pins, or coloured pencil, and their position recorded on a rough outline sketch of the article. The shape (smear, drop or splash), size, surface on which present (inside or outside), appearance (fresh, dirty, rubbed or washed) and presence of hairs or insect fragments so far as can be seen with a hand lens, should be ascertained.

There is at present no reliable test for the age of blood stains, the appearance and ease in dissolving being the only guides, though neither is conclusive. The rate of solution in arsenic trioxide solution or in dilute glycerine solution, as compared with that of stains of known age, has been suggested, but is not trustworthy. In one case that occurred in Egypt a razor much stained with blood was kept in the drawer of a desk in a police

[1] G. W. Baker, *Annual Report of the Government Analyst, Palestine*, 1929.

[2] In India the written permission of a magistrate or other judicial officer must be obtained before any portion of an exhibit may be removed. L. A. Waddell, *Lyon's Medical Jurisprudence for India*, 1914, pp. 165, 733. See also this book, p. 14.

station in the provinces for six months, and on receipt at the laboratory the stains appeared fresh and clean and looked as though they might have been made the previous day.

(*b*) WASHED CLOTHING. Sometimes even unstained portions of a garment that has been washed give a strong reaction with benzidine which may be due to incomplete rinsing from the blood-stained water. In such cases the hæmochromogen method must be used, though by employing a less sensitive benzidine solution than usual and observing which parts or stains give the quickest and most intense reaction and applying the confirmatory test only to these, the work may be shortened.

(*c*) INSECT MARKS ON CLOTHING. These will give the serum test for human blood if the insects have fed upon man. Spraying from an artery, as already stated, results in many small stains close together that resemble insect marks, the latter, however, usually being scattered. Microscopical search for parts of insects should be made in doubtful cases. The general condition of the garment and the social status of the accused also should be taken into account.

(*d*) SMALL OBJECTS, WEAPONS AND TOOLS. These should be placed on a large sheet of glazed paper and examined carefully with a lens, special attention being paid to all rough surfaces or rough edges, such as turned edges of knives or burred heads of hammers, on which blood may be entangled and that are difficult to clean. The space between the handle and the tang of a weapon or tool should be exposed (by cutting through the handle with a hack-saw) and examined. Scrapings or detached clot fragments should be tested with benzidine, as little as possible of the blood matter being used for the test. Rusted iron often shows a red, shining, cracked appearance very similar to blood, and the testing of such articles is often troublesome owing to positive reactions from all parts. Instances have been met with by Colles in which rust and also hæmatite undoubtedly have given the test. Dirty cooking knives soiled with remains of meat, dirt on the soles of boots, manure, articles found in lavatories may show a positive benzidine reaction. The remedy in such cases, short of trying each stain separately by the hæmin test or spectroscope, is to use a benzidine solution that is not very sensitive, so as to pick out the most likely stains and to apply to these a confirmatory test. The position of the stains, when important, may be recorded conveniently on an outline sketch of the article.

First Confirmatory Test for Blood. This consists in a microscopic examination for red corpuscles. In most mammals the red blood corpuscles are circular, biconcave discs without nucleus, an exception being the camel and certain closely related animals, such as the llama, whose red corpuscles are oval, but also without nucleus. In birds, fishes, reptiles and amphibious

animals the red corpuscles, which are generally larger than those of mammals, are oval and nucleated, the nucleus also being oval. The average size of the red corpuscles of human blood is larger than that of the red corpuscles of most domesticated animals, except the dog, the corpuscles of which are much the same size as those of man.

With fresh blood there is no difficulty in distinguishing between mammalian and non-mammalian blood or in differentiating camel blood from that of other mammals, but in the dried state the corpuscles are unrecognizable and even on being wetted again their condition is not much better, since, not only during drying (especially if this takes place slowly), but also on being wetted, they change both in form and size and recognition is always difficult and often impossible. In order to examine a blood stain, a minute fragment (taken from the thinnest part, that is from where the blood has dried quickly and hence where the corpuscles have undergone the least change) is transferred to a microscope slide by means of the point of a knife and moistened with Vibert's fluid (0·5 gram mercuric chloride and 2 grams sodium chloride made up to 100 c.c. with distilled water), allowed to stand for half an hour, teased out and examined under the microscope. The result, however, is often unsatisfactory and any measurement of the size of the corpuscles is useless on account of the changes they have undergone.

Second Confirmatory Test for Blood. If blood is boiled for a short time with glacial acetic acid and a trace of sodium chloride, characteristic crystals of "hæmin" (hæmatin hydrochloride) are deposited on cooling. A minute trace of blood only is necessary but the test requires practice and fails to respond if the blood has become difficultly soluble through exposure, putrefaction or contact with rust. The two methods of carrying out this test that are recommended from among the many modifications employed are: (*a*) by direct heating on a microscope slide, and (*b*) Beam and Freak's modification.

Method of Direct Heating. This method being quick, is recommended for cases in which fresh blood-stained fabrics or small clots are available. A few square millimetres of the stained fabric or scrapings or a minute clot are teased or crushed on a dry microscope slide and covered with a clean dry cover slip. If this makes very close contact with the slide, a small slip of filter paper or a hair should be introduced underneath it to provide sufficient space for the acetic acid. Glacial acetic acid [1] containing 0·1 per cent. of sodium chloride or of sodium iodide is then run in under the slip by means of a pipette until the space is full.[2] The slide is now heated cautiously and evenly over a small flame (the by-pass of a Bunsen burner) until the acid boils, and heating is continued until about half the acid has

[1] The acid must be glacial.

[2] Too much sodium chloride or sodium iodide produces unsatisfactory results.

boiled away. Gentle boiling is required, as it is not a matter of concentrating the acid solution of the blood but of subjecting the blood to the action of boiling acetic acid. Tapping the slide with forceps during the heating prevents superheating which may occur otherwise and which may result in the cover slip and acid being blown into the observer's face. More acid is now run in under the slip and the heating is repeated until about a quarter of the total acid has boiled away. The slide is allowed to cool and is then examined under a magnification of about 300 diameters. There are two points in the microscopical search for hæmin crystals to which attention should be directed specially, namely, first that the fabric or clot should be examined, when crystals may be seen entangled in the undissolved blood matter; and second, that if the boiling has been too prolonged, all the blood may have become dissolved out, in which case search should be made in the area just beyond the edges of the cover slip in contact with the remaining acid, when clusters of hæmin crystals may be seen mixed with those of sodium chloride.

The normal appearance of hæmin crystals is that of dark brown, long, narrow, thin, rhombic plates over-crossed as in an X or in clusters like a starfish. The X formation is very characteristic. With difficultly-soluble blood (old or heated blood) the rhombic plates are much shorter and broader and owing to ill-defined edges at the angles possess the shape of a bean, but, however, are quite characteristic to the experienced observer. Unsatisfactory hæmin crystals may be recrystallized by pushing the cover slip over them and heating gently for a short time and then cooling. In this way obstinate blood matter that does not give good crystals may be moved across the slide and repeated trials made.

This method is often troublesome in practice with old, heated, or washed blood or blood mixed with rust or muscle fragments. Matter obviously blood sometimes refuses to yield crystals in spite of repeated heating, due possibly to the presence of albumin. Rust is also troublesome, especially when combination with the hæmoglobin has taken place.

Possible Fallacies. Distinct brown crystals must be observed. Colourless needles of sodium chloride, if small, simulate hæmin crystals. Fragments of indigo-dyed fabric yield large crops of long narrow rhombic plates of a fine blue colour. These, however, are much larger than hæmin crystals and are distinguished easily by the colour. In cases in which dyed material is being examined a part of the unstained fabric should be treated with the boiling acid and examined as a control test.

METHOD OF BEAM AND FREAK.[1] This method is very reliable and most

[1] W. Beam and G. R. Freak, "On a Greatly Improved Hæmin Test for Blood, with Notes on some recently proposed Methods," *Bio-Chemical Journal*, 9 (1915), pp. 161–70.

valuable when minute quantities of material have to be dealt with and in cases of old, insoluble, or rust-combined blood. A drawback to the test, however, is that it requires considerable time, and it is recommended that the tubes be prepared one day and examined the next morning. The details are as follows :

" A small quantity of the suspected material is placed at the bottom of a flat arsenic sublimation tube about 6 by 3 mm. and 35 mm. long. A thin round ignition tube will answer if no flat tube is procurable, but for examination under the microscope the flat form is obviously better. A few drops of acetic acid containing from 0·01 to 0·1 per cent. sodium chloride are added and a very fine cotton thread adjusted so that its upper end is near the top of the tube and the lower end reaches to the bottom of the liquid. The thread should be everywhere in contact with the tube, to which it adheres readily by being moistened with the liquid. The adjustment is readily made by means of a glass rod one end of which is drawn out for the purpose. The tube is now placed in a rack, or supported by forcing its base into a small blob of plasticine, and allowed to remain until crystallization has taken place.

" Before placing the thread into position, the solution of the blood may be aided, if desired, by cautiously heating the tube over a small flame, loss of the liquid by explosive boiling being prevented by holding the finger tightly over the mouth of the tube.

" While such heating appears rarely to be essential, the long contact with the acid in the cold sufficing for solution in practically all cases, it is nevertheless advisable in that it gives at once an indication of the strength of blood solution obtained. For the best results this should be quite weak.

" The clear liquid, filtered by its passage through and along the thread, is slowly drawn up, by capillary action, to the mouth of the tube. Under these conditions evaporation takes place so slowly that, even when the temperature of the atmosphere is above 38° C., it is complete (if the tube is held in an upright position) only after 12 to 24 hours or more. The rate of evaporation is readily controlled, within wide limits, by altering the dimensions of the tube and the angle at which it is supported.

" The crystals usually begin to appear, on or near the upper half of the thread, and of sufficient size to be distinguished with a power of 75 diameters, in about an hour ; and they ultimately become so large that, in place of requiring a magnification of 250 to 300 diameters, as usually recommended, they may readily be seen with one of 25 diameters or even, in many cases, with a good hand lens. The crystals are best viewed against a dull white background. A piece of white paper is suitable.

" The extraordinarily large size of the crystals is due, in great part, to the slow evaporation of the liquid ; but it is also a result of the removal,

by the thread, of the interfering action of the blood albumin on crystallization. Examination of the thread at the end of the experiment shows that the soluble, non-crystallizable, constituents of the blood are carried to its upper end, and that the maximum growth of hæmin crystals is found lower down.

" If the solution is sufficiently weak, the first crystals form at the point of greatest concentration—the upper end of the thread; but as the albuminous matter accumulates these cease to grow and the largest and most numerous crystals are found, later, about midway down the tube.

" For the best results the following precautions should be observed:

" The tube should be thoroughly clean and dry. It is best cleaned by swabbing out successively with acetic acid, water, and alcoholic soda, followed by thorough rinsing with distilled water and drying on a hot plate.

" The thread should be clean and as fine as can be obtained. A good plan is to take No. 80 ' six-cord sewing machine cotton ' and to untwist it, using one of the ' cords ' for the test.

" The solution of the blood in acetic acid should not be concentrated, but very weak. The liquid should only be faintly pink. This ensures large crystals and clean fields.

" If the method is to be applied experimentally to fresh blood, the latter must be completely dried before the addition of the acid, and especial care should be taken to work with very dilute solutions."

Third Confirmatory Test for Blood. When examined spectroscopically hæmoglobin and its derivatives show characteristic absorption bands in the visible spectrum. This is a most valuable test that is simple in application, that may be applied to the most minute stains and that gives decisive results. For the purpose of the test a microspectroscope, such as the Abbé instrument made by Zeiss, is recommended. This is a direct vision spectroscope that fits into the microscope tube in place of the eyepiece and can be moved away from or brought over this at will and when in use is secured by a catch. At the side is an arrangement whereby a comparison spectrum of blood can be placed in juxtaposition to the spectrum under examination. The instrument is provided with a scale marked in wave lengths. Sutherland recommends a Zeiss modification of Browning's pocket spectroscope which can be fitted to the microscope.[1]

In legal practice the derivatives of hæmoglobin that are most useful are (*a*) Hæmochromogen (reduced hæmatin), (*b*) Hæmatoporphyrin, and, if the stain is fresh, (*c*) Oxyhæmoglobin or Methæmoglobin. These will now be considered separately.

HÆMOCHROMOGEN. When blood stains, consisting as they do of a mixture of oxyhæmoglobin, methæmoglobin and hæmatin, are treated with a powerful

[1] W. D. Sutherland, " Blood Stains," in *Lyon's Medical Jurisprudence for India*, 1914, p. 167.

reducing agent in the presence of a strong alkali, hæmochromogen (reduced hæmatin) is produced. This possesses two marked absorption bands.

The most efficient reducing agent is sodium hydrosulphite ($Na_2S_2O_4$). It is obtainable in the solid form, and a reliable solution may be made as follows: 2 grams of sodium hydrosulphite are shaken up in a test tube closed with a rubber cork with 5 c.c. of 10 per cent. potassium hydroxide solution and 1 c.c. of alcohol. The solution must be kept corked and should always be freshly prepared just before use.

Sutherland recommends ammonium sulphide with potassium cyanide, which yield cyanhæmochromogen, and his method is as follows: [1] Stains on a hard surface are moistened with potassium cyanide solution (10 per cent.), scraped off and smeared on a microscope slide. Stains on a soft fabric are immersed in boiling water for three seconds to fix the colouring matter, placed on the microscope slide and treated with potassium cyanide solution. To the stains thus prepared a few drops of yellow ammonium sulphide solution are added, a cover glass put on, the superfluous fluid absorbed by blotting paper and the slide examined. If blood is present, a cherry-red colour will be seen, which when examined with the spectroscope will show a dark band at 570–550 and another darkish band at 540–525, the latter, however, being sometimes so faint as to be almost invisible.

Another reducing agent is hydrazine, a solution of which is made as follows: 10 grams of sodium hydroxide and 5 grams of hydrazine sulphate are dissolved in 100 c.c. of water and 100 c.c. of 96 per cent. alcohol are then added. After standing a few hours the mixture is filtered. The suspected stain is treated with a few drops of the mixture.

Testing the Stain. It is not necessary to bring the blood into solution for observing absorption spectra; in fact, observation is easiest when a minute amount of blood matter, such as a clot or stained fibres of a fabric, can be brought into the field of the microscope in a sufficiently translucent condition to enable enough light to pass to give visibility of the spectrum. No objective smaller than $\frac{1}{4}$ inch should be used, or not enough light will be transmitted. If solutions of blood are prepared these are usually so dilute that a miniature observing cell must be made and filled. This is always necessary when the stain is on dark or opaque material. A simple cell may be made by cutting a length of one inch off the bottom of a $3 \times \frac{1}{4}$ inch sublimation tube or a smaller tube if the amount of solution available is very small, and supporting this in a hole in a piece of cork. The blood extract is run into this cell with a pipette and the cell is so arranged that the light passes through it longitudinally.

The microspectroscope having been fitted into the microscope, a powerful light, that of a demi-watt filament lamp being recommended, is concentrated

[1] *Ibid*

by the substage condenser and a brilliant spectrum produced with as small an opening of the slit as possible. The scale is now adjusted so that the sodium line, or the " D " line if sunlight is being used, lies at the correct position, namely 589.

A small portion of the stained fabric, or scrapings from the blood-stained article, are placed on a microscope slide moistened with a drop of pyridine, a few drops of the hydrosulphite reagent added and the slide adjusted under the objective. The reduction takes place in the cold and should the slide be heated the hæmochromogen spectrum will disappear. In most cases the spectrum is seen readily and can be identified with that of authentic hæmochromogen by means of the comparison spectrum. It is necessary to use a small slit and move the slide about until the spectrum is observed.

If the amount of blood is small or the material dark, it is best to focus a salmon-pink tinted blood fragment in the centre of the field before observing the spectrum.

For the comparison spectrum a small tube containing diluted blood, or a microscope slide on which is a fragment of blood-stained fabric that has been treated with a few drops of the hydrosulphite reagent is placed in a clip at the side and the mirror is adjusted until a brilliant spectrum is produced, when the bands of hæmochromogen will be seen clearly. These consist of an intense narrow band at 556 (mean) which is the most marked and easily produced band of any of those of the hæmoglobin derivatives, and a wider, fainter band at 530 (mean). It will be noticed that blood shows a salmon-pink tint on addition of the hydrosulphite reagent. This is characteristic. The width of the bands depends on the concentration of the blood, which should be such that the bands are distinct, but not too marked.

If the material is too opaque, even when teased or squeezed out, to show a pink zone giving the spectrum, an extraction with pyridine for about half an hour, the length of time depending on the solubility of the blood, should be made and the concentrated pyridine extract treated with the hydrosulphite reagent. If this fails, prolonged extraction with 10 per cent. alkali, or pyridine, should be tried, but probably the blood will be so insoluble that either Beam's hæmin test or the hæmatoporphyrin test must be applied.

The hæmochromogen test has been found to give almost instantaneous results with recent blood stains on white or slightly coloured fabrics. With blue indigo-dyed garments the colour of the fabric may be bleached completely in a few minutes by performing the test in a covered watch glass to exclude air, thus leaving the red hæmochromogen stain clearly visible. With fresh stains on knives or earth the test succeeds but requires more careful observation and focussing. The test is sensitive and reliable, even old insoluble stains on white fabrics giving a distinct spectrum. The

presence of the intense band is considered sufficient proof of the presence of blood, assuming that the control tests with unstained material in cases of dyed fabrics are satisfactory.

HÆMATOPORPHYRIN. Hæmoglobin when digested with concentrated sulphuric acid forms an iron-free purple pigment, hæmatoporphyrin, which shows three absorption bands, one at 608–594 and two others lying so close together as to appear often as one broad band 584–572 and 572–548. The bands are not so intense as that of hæmochromogen. The dry substance or fabric should be warmed cautiously and gently with concentrated sulphuric acid, avoiding charring, and the purple-coloured zone focussed and observed. A control test should be made by grinding a small quantity of dried blood up in a glass mortar with 1 c.c. of concentrated sulphuric acid and examining by means of the comparison spectrum. Only strong acid should be used, as moisture tends to precipitate the hæmatoporphyrin.

In alkaline solution hæmatoporphyrin exhibits four bands—620–612, 594–568, 553–536, 527–488. An alkaline solution may be made from the acid preparation by draining off the acid and adding concentrated potassium hydroxide solution. The alteration in the position of the bands affords a certain proof of the presence of blood.

This test, which should be regarded as the last resort for difficult stains, is especially applicable to old or insoluble blood and, if negative, there is no other test that is likely to succeed. It is not so easy of application as the hæmochromogen method. Hæmatoporphyrin gives a characteristic luminescence when exposed to ultra-violet rays.

OXYHÆMOGLOBIN. In recent stains the spectrum of this substance showing two bands, a narrow sharp band at 579 (mean) and a broader less marked band at 542 (mean), may be seen, with the bands of methæmoglobin possibly mixed with them. These spectra cannot be considered conclusive alone and the hæmochromogen spectrum must be produced by the addition of a reducing agent.

Possible Fallacies of the Spectrum Test for Hæmoglobin. Certain dye substances such as alkanet root, madder and cochineal exhibit absorption spectra simulating that of oxyhæmoglobin, but none of these shows a spectrum similar to that of hæmochromogen. In every case, therefore, in which dyed or coloured fabrics are examined, a control test should be applied by observing either more than one spectrum or the change in spectrum on the addition of certain reagents, since there is no known colouring matter, except that of blood, that gives the series of spectra described. Stains, too, that show absorption spectra, but do not give the benzidine test, cannot be considered positive unless confirmed by the hæmin test.

The Origin of the Blood. If a living animal is injected several times at intervals of some days with small quantities of sterile human, or other blood serum, the blood serum of the animal injected acquires the property of producing a precipitate when added in small amount to the blood serum of the kind of animal employed for the injection, or of an animal closely related to it, and the reaction is specific. The test is known as " The Precipitin Test," and the prepared serum, for the production of which rabbits are employed generally, is termed " Antiserum." This test is now recognized by the Law Courts of most countries.

Under the ordinary conditions of the routine test it is not possible, nor is it usually necessary, to distinguish between the blood of animals of closely related kinds. Thus dog blood and fox blood give a similar reaction and accordingly are classed together as " canine " ; for the same reason, sheep and goat blood are classed as " ovine " ; cow, ox and buffalo blood as " bovine," and bird blood, of whatever kind the bird may be, as " avian." The further differentiation, however, is not impossible. Sutherland uses a method of dilution,[1] the antiserum prepared from a rabbit being diluted with normal rabbit serum until it no longer gives the group reaction and therefore may be employed for the specific test. Weichardt employs an adsorption method.[1] Thus, to prepare an antiserum that will precipitate serum *a*, but not the related serum *b*, take anti-*a* serum, add to it serum *b*, allow to stand and filter off the precipitate resulting from the group reaction : the filtrate will now only precipitate serum *a*. Relationships that are more distant may be distinguished by comparing the amount of the turbidity and the time required for its formation. Thus all ruminants are akin, but the blood of an ox and that of a goat may be differentiated by testing them with both anti-ox and anti-goat serum, the particular serum that gives the greatest and most rapid reaction indicating which of the two it is.

Although it is frequently stated that with the precipitin test the blood of anthropoid apes may be mistaken for human blood, Sutherland found, after repeated experiments, that the former gave practically no reaction with human antiserum.[2]

A particular kind of blood reacts in the normal manner even when it is mixed with other unrelated bloods.

Antiserum. The method of preparing antisera has frequently been described and need not be repeated, but reference may be made to Roche

[1] G. Roche Lynch, " The Technique of the Precipitin Test and its Forensic Value," *Analyst*, 53 (1928), pp. 12–13.

[2] W. D. Sutherland, " Note on 2,643 Medico-Legal Cases in which 6,566 Articles suspected to be Blood-stained were examined." *The Indian Journ. of Medical Research*, 3 (1915–16), pp. 205, 217.

Lynch's description when rabbits are employed [1] and Sutherland's description when using domestic fowls.[2]

Although antisera may be purchased ready for use, it is preferable, if possible, for the expert to prepare them for himself, but whatever the source may be, it is essential that they should be examined carefully and tested before use, in order to make sure that they are perfectly clear, specific and highly potent, and, when not prepared by the expert, that they are in fact the kind of antisera they are labelled or are supposed to be. Antisera should always be kept in closed tubes and stored on ice and when required they should be warmed slowly to room temperature.

Preparation of the Blood Extract. Blood in forensic cases will necessarily be in the form of stains on various objects and, before these can be examined, an extract must be prepared from them, which is done by soaking a small fragment (cut into tiny pieces) of the material (if a textile fabric) or a scraping (when the stain occurs on wood, metal, plaster, leather or other solid object) in physiological saline (0·9 per cent. sodium chloride solution in water) and incubating at blood heat (37° C.), the time of incubation varying with the age of the stain, twenty-four hours, however, being the usual period required. The extract is then filtered or centrifuged and must not be used on any account unless it is perfectly clear.

A simple and efficient method of filtration devised by Willcox [3] is to pack a few shreds of torn filter paper into a small glass pipette at the point where the tube begins to narrow; add the extract to be filtered above the packing (which may be done by means of another pipette); fit on the wide end of the pipette a rubber teat and by compressing this the extract may be forced through the filter paper and thus clarified. Roche Lynch [4] plugs one limb of a very small U-tube with filter paper, adds the extract above the plug and connects the other limb of the tube to a filter pump.

In the case of stains difficult of solution, Sutherland recommends [5] the addition of a few drops of potassium cyanide solution to the saline used for extraction, but even with refractory stains, simple saline is usually sufficient if a longer time is allowed for the extraction and the result is better, as the extract is free from any complications due to the alkali of the cyanide, which must be neutralized before the precipitin test is applied.

In order to obtain reliable results with the precipitin test the blood extract must be absolutely neutral in reaction, Graham-Smith and Sanger having

[1] G. Roche Lynch, "The Technique of the Precipitin Test and its Forensic Value," *Analyst*, **53** (1928), pp. 6–7.
[2] W. D. Sutherland, "Blood Stains," *Lyon's Medical Jurisprudence for India*, 1914, pp. 174–5.
[3] W. H. Willcox, "The Biological Test for Blood," *Analyst*, **53** (1928), p. 3.
[4] G. Roche Lynch, *Analyst*, **53** (1928), p. 6.
[5] W. D. Sutherland, *Lyon's Medical Jurisprudence for India*, 1914, p. 176.

shown many years ago that the presence of even small quantities of either acid or alkali modifies the amount of the precipitate obtained.[1] Glaister, who repeated the earlier work, found [2] that both intense acidity and intense alkalinity prevented the occurrence of the precipitin reaction, that slight acidity intensified it and that slight alkalinity reduced it. Before use, all extracts should be tested with litmus paper, and if found other than neutral, they must be neutralized, if acid, by the careful addition of a few drops of a dilute solution of sodium carbonate and, if alkaline, by the addition of a dilute solution of tartaric acid. When a blood stain is likely to give an acid extract, as in the case of most stains on leather and those on certain kinds of wood, it should be extracted with saline containing a little magnesium oxide in suspension.

Colles found that concentrated extract of human hair (after washing with light petroleum spirit) gave only an almost imperceptible reaction after five minutes with an extremely powerful antiserum and that a concentrated extract from finger nail clippings also gave a negligible reaction under the same conditions. Blood on hair or nails, therefore, may be tested satisfactorily for human origin.

Strength of Extract. The approximate strength of the blood extract used for testing must be known, since with powerful antisera and strong blood solutions a faint turbidity (Mammalian Reaction) due to a precipitin common to all mammals may be produced, and in order to exclude this, as it might be mistaken for a weak positive precipitin reaction, it is necessary to use dilute blood extracts (about 1 : 500 or 1 : 1000) with powerful antisera. The strength of the extract may be judged by one or other of three tests, which may now be described.

Foam Test.—When air is blown into a solution containing blood serum by means of a pipette, or when such a solution is well shaken, foam is produced and it is usual to estimate the strength of the solution (*i.e.* the amount of serum present) by the intensity and duration of the foam when compared with solutions of known strength. Naturally the results can only be approximate. This test has been investigated by Glaister,[3] who is in agreement that while it is valueless as a means of determining the exact strength, it gives useful approximate results in the hands of an experienced observer.

Nitric Acid Test. This test depends upon the degree of opalescence produced when a drop of 25 per cent. nitric acid is added to a blood extract.

[1] G. S. Graham-Smith and F. Sanger, "The Biological or Precipitin Test for Blood considered mainly from its Medico-Legal Aspect," *The Journ. of Hygiene*, **3** (1903), pp. 258–91, 354–64.

[2] J. Glaister, *Trans. Medico-Legal Society*, **21** (1926–7), pp. 11–12.

[3] J. Glaister, *Trans. Medico-Legal Society*, **21** (1926–7), pp. 4–6.

If the opalescence is faint, it is assumed that the strength of the extract is approximately 1 : 1000 and on this assumption other strengths may be made. If the opalescence is considerable the extract is diluted with normal saline until only a faint milkiness is produced, when the strength is assumed to be about 1 : 1000. This test is not satisfactory.

Salicyl-sulphonic Acid Test.[1] Salicyl-sulphonic acid precipitates proteins, giving a delicate opalescence in dilutions of about 1 : 12,000 and upwards of blood. If, therefore, a series of dilutions of the extract be compared with known dilutions of blood, to both of which salicyl-sulphonic acid (50 per cent. strength) has been added, the degree of opalescence produced may be matched and so an approximate estimate of the strength of the extract may be obtained.

Glaister estimates the strength of blood extracts from the size of the stain used to make the extract.[2] He assumes that a stain the size of sixpence represents one drop of blood and as he uses 6 c.c. of saline for the extraction, each c.c. of which is assumed to represent 16 drops, the resultant dilution is approximately 1 : 100, and from this other dilutions are obtained. Blood, however, becomes partly insoluble on drying, and it is doubtful whether it can ever be extracted quantitatively and hence the strength of the extract would generally be less and probably often considerably less than that calculated by Glaister.

The Precipitin Test. Among the various methods of applying the test adopted by different workers the four principal ones are as follows :

1. To place the antiserum in small taper tubes and to run in carefully above it a layer of the extract to be tested, so that a sharp division is formed, at the junction of the two liquids. This is recommended by Roche Lynch.[3]

2. To place the extract to be tested in the tube and to add the antiserum drop by drop or to run it down the side of the tube, when in either case it mostly sinks to the bottom, forming a fairly sharp line of division between the two liquids.

3. The capillary-tube method (Micro-Precipitin Test) devised by Colles, which is both rapid and accurate and is particularly useful when large numbers of stains have to be examined and economy of antisera becomes necessary. This method will be described in detail later.[4]

4. A microscopical method described by Haddon, the details of which will be given later.[5]

After the one liquid is added to the other the mixture is allowed to stand, any reaction that takes place being noted. The time allowed is usually 20 minutes in Britain, but only 2 minutes in Germany ; 2 minutes with

[1] G. Roche Lynch, *Analyst*, **53** (1928), p. 9.
[2] J. Glaister, *Trans. Medico-Legal Society*, **21** (1926–7), pp. 4–6.
[3] *Ibid.*
[4] See p. 42.
[5] See p. 45.

the Colles modification and 30 minutes with the microscopical method. In the first three methods the reaction, which should be examined against a black background, takes the form of an opalescence that appears first at the junction of the liquids, then spreads and becomes denser and finally, if left long enough, a flocculent deposit is produced at the bottom of the tube.

Results of the Precipitin Test. These may be positive, negative or inconclusive.

Positive. If the extract gives a definite result with one antiserum (or at most with two, if related) and remains clear with other antisera and if the control tests are satisfactory, the result is positive.

Negative. If a strong neutral extract has been tested with a powerful antiserum without result for fifteen minutes and if the control tests are satisfactory, it may be stated positively that the blood tested for is not present.

Inconclusive. If turbidity is produced with different antisera, there may be a mixture of bloods present, though usually such turbidity, which is generally intense and rapidly formed, is due to acid substances in the extract acting as precipitants for the albumins of the antisera. The remedy is to neutralize the extract with a few drops of dilute solution of sodium carbonate or to digest it with magnesium oxide and filter.

Control Tests. The results of the precipitin test can be considered complete and reliable only after rigid control tests have been made. Thus the antiserum giving a positive result must be proved to be specific for the particular blood under examination by obtaining positive results with known specimens of that blood and negative results with known specimens of other blood, particularly any other kind of blood likely to be present. The antiserum also must be proved to be powerful by testing it with dilute solutions of the blood under examination. It must be free too from mammalian reaction when observed for fifteen minutes after mixing with a 1 : 100 extract of blood of the kind alleged or thought to be present and must remain clear when mixed with (*a*) normal saline, (*b*) extract of an unstained portion of the fabric or object under examination, and (*c*) any potassium cyanide solution used in the extraction.

Antiserum having a marked mammalian reaction and any blood extract that cannot be cleared perfectly should be rejected and replaced by fresh material.

Micro-precipitin Test. To overcome the difficulty of preparing clear extracts of small stains without loss or overdilution of the extract, the following method was devised by Colles and has given good results after several years' use in Egypt:

The stains or scrapings are placed in small square white glass blocks having a circular hollow basin-shaped cavity, such as are used by pathologists for staining sections, moistened with a drop or two of normal saline and thoroughly teased out until the whole fabric is wetted. Clots or dust are ground with a glass rod. Although the test will succeed with very small stains if the albumin is still soluble it is better to take at least two square centimetres of the stained fabric. Enough saline is now added drop by drop to ensure excess of liquid beyond that soaked up by the material, so that, if the pot is tilted, supernatant liquid will flow easily to the side. Usually, four to six drops of saline are sufficient, but as little as possible should be used. The pot is covered with a square of glass and placed in a damp chamber (a desiccator with water) and, in hot weather, in order to avoid putrefaction, the desiccator is put in the ice chest and left until next morning.

In the tropics and sub-tropics extracts usually require at least twelve hours' extraction owing to the climatic conditions tending to cause greater insolubility of the blood than in temperate climates. If necessary, however, tests may be made after a few hours' extraction, and, if the results are not positive or conclusive, the extraction should be allowed to proceed overnight and the tests repeated. If very spongy material such as thick wool, that soaks up much liquid, is under extraction, it is a good plan to squeeze it out with a glass rod after six hours' extraction and then leave it overnight. This ensures thorough mixing of the extract. Next morning, the pot is taken out of the ice chest and is allowed to warm up to room temperature.

A number of capillary tubes about 12 to 15 cm. long and 1 mm. diameter are made by drawing out test tubes in the blowpipe and cutting up the capillary so produced into lengths. These should be made just before use or kept stored in corked tubes, as, if dusty or dirty, the reaction is obscured.

The tubes of antisera having been allowed to warm up slowly to room temperature are opened and drops of the antisera placed on white tiles with hollows such as are used for volumetric " outside " indicators, using sterile pipettes. The tiles are labelled anti-human, anti-bovine, anti-avian and so on respectively, and 1 : 500 solutions of human, bovine or avian serum are prepared in normal saline, especially that of any blood which may be alleged by the accused to be the origin of the stains, and also a blank extract of the material or fabric upon which the blood is found. The antisera should now be tested as described under Control Tests.[1] The control tests having been made the suspected stains are examined as follows :

The white glass pot containing the case under test is cautiously tilted by pushing some microscope slides under one side and a little of the supernatant liquid, which should be clear and will be coloured according to the

[1] See p. 42.

amount of hæmoglobin present, is drawn off into a capillary tube held slightly obliquely. A column about ½ to 3 cm. long should be drawn off, but less will suffice if only small quantities of extract are available. If this is done cautiously, avoiding any floating matter by holding the capillary almost parallel to the surface of the liquid, a clear column of extract is obtained. This method which avoids filtration of minute amounts of solution, replacing it by decantation, has been found to give clear extracts with scrapings from such objects as rusty knives, bricks, earth and wood. The clear liquid is now blown out on to a watch glass and tested for serum concentration by blowing bubbles in it or by drawing off a minute quantity in another capillary tube and then drawing up a drop of 25 per cent. nitric acid and comparing the turbidity with that produced by one of the 1 : 500 serum dilutions treated in the same way. If the extract is too concentrated, drops of saline are added and the mixture stirred. It must also be tested for neutrality and, if not neutral, it is made so by treatment either with magnesium oxide or with dilute tartaric acid solution. Columns of the diluted extract of 2 to 3 cm. length are now drawn up into two capillary tubes, the tubes being held one in each hand. That in the right hand is immersed in a drop of anti-human serum or that antiserum corresponding to the blood which the accused is alleged to have shed. A column of antiserum about 2 cm. in length may be induced readily to run up into the capillary by holding it obliquely. Care should be taken that no air bubbles collect between the column of blood extract and the column of antiserum. The capillary held by the left hand is introduced into a drop of antiserum for the blood claimed or supposed to be present, and a column drawn up in the manner described.

The two tubes held obliquely, one in each hand, are now viewed against the shadow cast under the working table, it having been arranged previously that no light comes from the side of or from behind the observer. In this way, the appearance of a faint colourless ring at the point of contact of the extract and antiserum is detected easily. Within one minute or, at the most, two minutes (according to the strength of the antiserum) a turbid ring should be observed if blood corresponding or related to the antiserum is present. If, as is usually the case, the right-hand tube is positive, human blood or the suspected blood is present. The tubes are now supported in an oblique position in plasticine on a horizontal wooden rod fixed in a retort stand and their position numbered and recorded.

If a positive result with abundant turbidity has been obtained, a control test using another capillary should be made immediately with a greater dilution and the result confirmed. At the end of five to ten minutes, the turbidity should have collected into flocks of colourless matter resembling aluminium hydrate. The second capillary tube should remain perfectly

clear; if a turbidity is produced, this may be due to mixed bloods or to acidity. If no result is observed in five minutes with the suspected blood antiserum, the test should be repeated with undiluted extract. If negative results are obtained, tests should be made with other antisera using undiluted extract until a result is obtained. This, however, may not be possible always owing to lack of the necessary antisera. In this way a number of tests may be made with a few drops of extract.

The advantages of this method are (*a*) that small quantities of clear extract are obtained easily even from powdered material, (*b*) that a considerable number of tests may be applied to a drop or two of extract, (*c*) that the tests are repeated easily. The antiserum rising inside a tube wetted with the extract mixes at once with it in sufficient quantity to ensure precipitin reaction. The drawbacks of the method are twofold, namely first the difficulty experienced with porous material and, second, that as the extract must not be shaken or stirred the concentration of the supernatant layer may be weaker than that at the bottom of the pot. This cannot be avoided entirely but may be diminished by stirring or testing the mixture the last thing before leaving the laboratory in the evening.

The Precipitin Test Microscopically. This method, which has recently been proposed by Haddon,[1] is described as follows: "Drops of antiserum are placed on microscope slides and . . . are spread over a small area to form circular films. The films are allowed to dry and drops of the various test fluids are then deposited on the films. The slides are placed in a moist chamber and examined after an interval of thirty minutes, under the low power of a microscope.

"In a positive reaction the film of antiserum becomes markedly granular, and when disturbed breaks into insoluble granular fragments, which may in many cases be easily observed with the naked eye. When the reaction is negative the film of antiserum goes into clear solution and no granular fragments are observed microscopically.

"A similar method may be used for the approximate estimation of the protein concentration of the fluids under examination. A drop of the fluid is placed on a dry film prepared with a 1 per cent. solution of tannic acid and 1 per cent. of acetic acid in physiological saline and the result is compared with those obtained with serum dilutions of known strength."

Blood Grouping

It has been found that every individual yet tested and probably, therefore, every individual in the world, may be classified into one of four groups, according to (*a*) the manner in which the serum of his blood reacts with the

[1] L. C. Haddon, "A New Method of Applying the Precipitin Test," *Analyst*, 59 (1934), p. 342.

red corpuscles of the blood of individuals of the other three groups and (*b*) the manner in which the red corpuscles of his blood react with the sera of the blood of individuals of the other three groups, the reaction in each case being an agglutination (clumping) of the corpuscles. This phenomenon persists unchanged with fresh blood throughout life and for at least some considerable time after the blood has been shed,[1] and may be obtained also from mummified tissue.[2]

The accepted international classification of these groups is as follows :

Group O. Serum agglutinates corpuscles of Groups A, B and AB ; corpuscles not agglutinated by any serum.

Group A. Serum agglutinates corpuscles of Groups B and AB ; corpuscles agglutinated by sera of Groups O and B.

Group B. Serum agglutinates corpuscles of Groups A and AB ; corpuscles agglutinated by sera of Groups O and A.

Group AB. Serum agglutinates no corpuscles ; corpuscles agglutinated by sera of Groups O, A and B.

Expressed graphically these results are :

Serum.	Corpuscles.			
	Group O.	Group A.	Group B.	Group AB.
Group O .	-	+	+	+
Group A .	-	-	+	+
Group B .	-	+	-	+
Group AB .	-	+	+	+

In 1927 two further agglutinable factors, M and N, were found in human blood corpuscles. These make three possible types MN, M and N, which are independent of the Groups O, A, B and AB and provide means of confirming them.

The value of blood grouping in forensic cases is apparent. Thus, if in connexion with a murder, a suspected individual has clothes or other objects in his possession that are stained with human blood and, if it be shown that this blood does not belong to the same group as that of the victim, this is strong evidence of innocence. On the other hand, an agreement in blood grouping between that of the stains and that of the victim may be confirmatory evidence of guilt, unless the suspect also belongs to the same group, when the stains may be those of his own blood.

[1] Lynch and Martley have obtained reactions with stains fifteen months old. G. Roche Lynch, *Trans. Medico-Legal Society*, 18 (1923-4), p. 71.

[2] W. C. Boyd and L. C. Boyd, (*a*) "An attempt to determine the Blood Groups of Mummies," *Proc. Soc. for Experimental Biology and Medicine*, 31 (1934), pp. 671–672 ; (*b*) "Blood Grouping Tests on 300 Mummies," *Journ. Immunology*, 32 (1937), pp. 307-319.

In paternity cases the tests for blood grouping may occasionally be of considerable importance in establishing non-paternity since blood grouping follows the Mendelian laws of heredity and from the blood grouping of the child, the mother and the alleged father respectively, it may sometimes be shown with certainty that the latter could not possibly be the father of the child in question.[1] [2] [3] [4] [5] [6]

Method of Determining Blood Groups. The group to which any particular blood belongs may be determined, either by testing the serum of the unknown blood against the corpuscles belonging to known groups, or by testing the corpuscles of the unknown blood against sera of known groups, the latter practice usually being followed, corpuscles of the unknown blood being tested against sera of Groups A and B. This is done as follows : [7]

Place a drop of Test-serum A (anti-B) on the left half of a microscope slide (which need not be sterile, but must be clean and dry) and a drop of Test-serum B (anti-A) on the right half of the slide. Puncture the ear or the finger of the individual to be tested and transfer to each of the sera on the slide about one-third of a drop of the blood on the end of a glass rod, using a separate rod for each transfer, and mixing the blood intimately with the serum. The blood must be transferred before coagulation has commenced ; gentle rocking of the slide accelerates agglutination. Martley improves this method by washing the blood before use with physiological saline solution in order to remove from the corpuscles as much of the serum as possible.[8]

The red corpuscles make a uniform suspension in the serum, which persists if there is no agglutination. If, however, the test is positive and agglutination takes place, this usually appears in less than a minute in the form of clumps of corpuscles readily seen by the naked eye, but better examined microscopically, using a low power. If the unknown blood belongs to Group O neither preparation shows agglutination ; if it belongs

[1] G. Roche Lynch, " The Medico-Legal Importance of Blood Grouping," *Trans. Medico-Legal Society*, **18** (1923-4), pp. 71–5.

[2] F. C. Martley, " Technique for Blood Group Determinations," *Trans. Medico-Legal Society*, **18** (1923–4), pp. 76–9.

[3] F. C. Martley, " The Use of Blood Grouping Reactions in Forensic Investigations," *Analyst*, **53** (1928), p. 17.

[4] G. R. Lynch and F. C. Martley, " Forensic Importance of Blood Groups," *Lancet*, 1924, p. 913, and *Analyst*, **49** (1924), pp. 293–5.

[5] F. Schiff, " Medico-Legal Significance of Blood Groups," *Lancet*, 1929, pp. 921–2, and *Analyst*, **55** (1930), pp. 59–60.

[6] S. B. Hooker and W. C. Boyd, " Blood-Grouping as a Test of Non-Paternity," *Journal of Criminal Law and Criminology*, **25** (1934), pp. 187–204.

[7] W. Byam and R. G. Archibald, " Transfusion of Blood," in *The Practice of Medicine in the Tropics*, **1** (1921), pp. 656–60.

[8] F. C. Martley, " The Use of Blood Grouping Reactions in Forensic Investigations " *Analyst* **53** (1928), p. 15.

to Group AB both show agglutination, and if it belongs to Group A or Group B only one shows agglutination, Group A serum agglutinating Group B corpuscles, and Group B serum agglutinating Group A corpuscles. With blood belonging to Groups A, B or AB the results obtained will be positive and the test sufficient, but with blood belonging to Group O, in which the test is negative, the result should be confirmed by using the serum of the unknown blood, in place of the whole blood or the corpuscles, and testing it with corpuscles of Groups A or B, when a positive reaction will be obtained.

The agglutinating reaction, however, as already stated, is not confined to fresh blood, but may be obtained from a dried residue of blood, such as a dried stain. This may be done in either of two ways, namely, by extracting the serum from the stain and testing it against corpuscles of known groups, or better by demonstrating the presence in the stain of corpuscles of a certain group by means of known sera. In the first method, Martley [1] frees the stain as much as possible from surrounding material; cuts it into very fine strips; places these in a miniature test tube; adds a small amount of distilled water; seals the tube and incubates it at blood heat for twenty-four hours; clears the liquid in the manner recommended by Willcox [2] by placing it in a small pipette, the commencement of the narrowest part of which has been packed with a few shreds of torn filter paper, and forcing the liquid through by compressing a rubber teat attached to the wide end of the pipette. The serum so obtained is then tested in the usual manner. Schutze [3] grinds the dried blood with 1 c.c. of distilled water in a small mortar and clears the liquid by centrifuging.

The second method, which is due to Martley,[4] depends upon the agglutinating power of a serum being finite and the method employed is to treat a known serum with the unknown corpuscles of the stain and afterwards to test the agglutinating power of the serum on corpuscles of known groups, noting whether its agglutinating power has been impaired and, if so, with which corpuscles. For instance, if a Group O serum, which agglutinates corpuscles of Groups A, B and AB, is treated with corpuscles of Group A, it can still agglutinate corpuscles of Groups B and AB, but its action on Group A corpuscles is impaired or lost. From the results obtained the group of the unknown corpuscles of the stain may thus be ascertained.

[1] F. C. Martley, "Technique for Blood Group Determination," *Trans. Medico-Legal Society*, 18 (1923-4), pp. 77-8.

[2] See p. 39.

[3] H. Schütze, "Hæmagglutination and its Medico-Legal Bearings," *The British Journ. of Experimental Pathology*, 2 (1924), p. 26.

[4] F. C. Martley, (*a*) *Analyst*, 53 (1928), p. 15; (*b*) *Trans. Medico-Legal Society*, 18 (1923-4), pp. 78-9.

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CHAPTER III

CLOTHING

THERE are few articles that afford so many clues to the personality, habits and history of the owner as clothes and few articles better repay careful examination, which in the main is chemical, and therefore work for the chemico-legal expert. Clothes may be considered under various aspects, for example in relation to the nature of the material of which they are made, their age and state of repair, and the stains, marks, dust and dirt that may be found upon them; but there are also other features, too numerous to specify, to be taken into account, and each case should be considered as a separate and special study.

Before being sent to the expert, clothes, if wet, should be dried, which should be done with care and with as little handling as possible. Each garment should be wrapped in a separate sheet of clean paper or clean cloth, tied, sealed and marked with a distinguishing number or letter. The parcel or parcels should then be packed further in stout paper or in a box. When a label is attached directly to an article of clothing it should be stitched on and not gummed or pasted.

For the purposes of examination, the clothes should either be hung up or be spread upon a large table. A good light, which should be daylight and not artificial light, is essential. The examination is generally very disagreeable, as clothes are often blood-stained, sometimes wet and usually dirty.

The kind of garment, the material, colour and condition should be recorded. Sometimes clothes are submitted for a specified purpose, as for example to ascertain whether there are stains of a particular kind or for the determination of the nature of certain manifest stains or for the examination of holes with a view to ascertaining how they have been caused, whether for instance by acid, burning, shot or bomb fragments. In such cases, beyond a general inspection of the clothes to enable them to be described in the report and identified again in Court, the examination is limited to the specific purpose required. In other cases the clothes should be examined in detail, special attention being directed to any tailor's name or mark, to any inscription on the buttons, to the nature and condition of the lining, to any holes or repairs, and particularly to the pockets, and all dust and dirt in these should be examined carefully.

In the case of stains and holes, the position, size and general appearance should be recorded, and it will be found very helpful in writing the report and for future reference if an outline sketch giving these particulars is

made in the laboratory notebook at the time of the examination, or better if a photograph is taken of them. This latter, however, is not always possible.

Before testing for stains clothing should be examined with a lens and whenever possible also by the ultra-violet rays, on exposure to which certain stains give a marked and characteristic fluorescence. That blood stains invisible in ordinary light may be revealed when exposed to ultra-violet rays or when photographed with infra-red sensitive plates has been mentioned already,[1] but stains other than blood also may become visible [2] [3] and these tests therefore should be used if possible. As a rule before applying chemical tests the substance producing the stains should be dissolved out of the cloth. In order to do this the solvent should not be applied directly to the garment, as this causes the stains to spread and results in considerable loss, and also because a large amount of solvent is required, which is soaked up by the cloth and must be squeezed out again, a process that it is impossible to carry out without contamination and further loss. The best procedure in most cases is to cut out portions of the stains [4] and soak them in the appropriate solvent. The whole stained area should not be taken, sufficient always being left for subsequent reference and further examination if necessary. The solution obtained is then tested, and reliance should never be placed upon the result of any one test, but as many confirmatory tests as possible should be applied. A control experiment should always be made with a portion of the cloth free from stains.

Acid Stains. The fact of acid stains on clothes, and holes caused by acid, is frequently useful as evidence in connexion with such crimes as acid-throwing, the making of explosives or bombs and the forgery of bank-notes, in which latter process acid may be used for etching purposes.

In order to ascertain whether a given stain is acid or not, a piece of blue litmus paper moistened with distilled water is pressed against the spot. This should be done by means of a glass rod, and never with the fingers, as in warm weather or in a hot climate the fingers may be sufficiently acid with perspiration to redden the litmus.

The tests of the various acids likely to be present may be described. Only qualitative testing is required, any quantitative determination being unnecessary, as it serves no useful purpose to know the exact amount of acid present.

[1] See p. 24.

[2] F. W. Martin, (*a*) *The Lancet*, **22**, vol. 1 (1933), p. 1206 ; (*b*) *The Police Journal*, **7** (1934), pp. 432–6.

[3] C. T. Symons, *Report of the Government Analyst, Ceylon, for the Year* 1930 (*Analyst*, **56** (1931), pp. 667–8).

[4] See footnote, p. 29.

Sulphuric Acid. Strong sulphuric acid, which is the acid generally used for throwing at the person, and which is also used for making explosives and in bombs, acts energetically upon cotton and linen fabrics, destroying the material and almost instantly producing holes: on woollen fabrics the action is less pronounced. The colour produced upon clothes by sulphuric acid or other acid depends to some extent upon the colour of the cloth and the nature of any dye present, and with sulphuric acid it varies generally from red to reddish-brown.

Taylor recommends [1] that the stained fabric should be digested in rectified spirit at a gentle heat. This is intended to avoid the solution of sulphates. Sulphates, however, although insoluble in absolute alcohol, are slightly soluble in rectified spirit, and are dissolved by weak alcohol, and therefore if the clothing is wet or the alcohol not strong misleading indications may be produced. Sodium hydrogen sulphate too, which conceivably might be present, is acted upon readily by alcohol with the liberation of free sulphuric acid which is partly converted into ethyl hydrogen sulphate.[2] Alcohol also is always slightly acid, and this might introduce an error, since it is acid for which search is being made. Water is the best solvent for sulphuric acid, and should be used. If, however, there is a large area of staining, it is useful to cut out an additional portion, extract it with alcohol, evaporate to dryness, take up in water, boil to decompose any ethyl hydrogen sulphate present and make a confirmatory test. The best tests for sulphuric acid are the acidity test with litmus and the white precipitate with barium chloride insoluble in hydrochloric acid.

Nitric Acid. Nitric acid may be used criminally in the making of explosives or for etching purposes in connexion with the forgery of bank-notes, and is occasionally used for throwing at the person and has been so employed on several occasions in Egypt. This acid is not so immediately destructive of clothing as strong sulphuric acid, but the stained areas, which, if the clothing is of wool, or contains wool, are of a yellow colour, eventually become very friable and break into holes.

Nitric acid should be extracted with water, and is best tested for as follows:—Neutralize the solution with a few drops of sodium carbonate solution to prevent loss of free acid by volatilization and evaporate to dryness over a water-bath in a small platinum or porcelain basin; moisten the residue with about 0·2 c.c. of phenolsulphonic acid,[3] allow to stand for a few minutes, and transfer by means of a jet of water from a wash bottle to a small beaker, using the minimum amount of water possible: add

[1] F. J. Smith, *Taylor's Principles and Practice of Medical Jurisprudence*, **2**, 1920, p. 391.

[2] G. S. Butler and H. B. Dunnicliff, "The Action of Alcohol on the Sulphates of Sodium," *Journ. Chem. Soc. Trans.*, 1920, pp. 649-67.

[3] See pp. 189-190.

strong ammonia in excess. An intense yellow colour indicates nitric acid. Any brown coloration should be disregarded.

In one case of acid-throwing fragments of a bottle were submitted for examination. This contained traces of acid that proved to be nitric acid, but an extraordinary feature of the case was that the neck of the bottle was stoppered with a screw of paper that contained crystals of oxalic acid.

Hydrochloric Acid. This is used less for criminal purposes than either sulphuric acid or nitric acid. It is also less energetic in its action than either of the acids mentioned. Stains on dark clothes caused by hydrochloric acid are usually of a red or reddish-brown colour. This acid is extracted best with water, and is tested for in the usual way by means of silver nitrate, with which it forms a white precipitate insoluble in nitric acid but readily soluble in ammonia.

Picric Acid. In several instances in connexion with bomb outrages in which picric acid was employed as the explosive material, the presence of characteristic yellow stains of this substance on clothing has provided valuable evidence.[1] The best solvent for picric acid is alcohol. If other solvents are used, the picric acid may escape notice, since solutions of this substance in petroleum spirit (petrol, benzine), chloroform and benzene (benzol) are practically colourless, which is also the case with ether solutions when the ether is absolutely dry. The alcohol solution is evaporated to dryness on a water bath, and the acid redissolved in water and tested. The most satisfactory tests are the colour, which is an intense yellow, the acidity to litmus, the extremely bitter taste, the dyeing properties with wool and silk, the red coloration on warming with a few drops of a saturated aqueous solution of potassium cyanide and the green precipitate with ammonia-copper sulphate, which later, however, may not be formed for about twenty-four hours if the solution is very dilute. The dyeing test should always be made, since the result, which is very characteristic, is one that can be exhibited in Court.

Oil and Grease Stains. Oil and grease stains on clothing are sometimes of importance, particularly stains of paraffin oil (kerosene) in cases of suspected incendiarism. Generally such stains are very manifest, but if the amount present is small and the clothes dark coloured or dirty they may escape notice unless special search is made. Oil (except paraffin oil) and

[1] In India the flesh and clothes of a victim of a certain bomb outrage were stained yellow, not by picric acid, but by sulphide of arsenic, bombs containing this compound used with potassium chlorate being common in the Madras Presidency. C. Newcomb, *Report of the Chemical Examiner for the Year* 1924, *Government of Madras.* Also Reports for 1930 (*Analyst*, 56 (1931), p. 666) and 1933 (*Analyst*, 59 (See note p. 57) (1934), pp. 543–4). A similar mixture has also been employed for bombs in Siam (A. Marcan, " The Chemist in the Far East," *Institute of Chemistry Lecture*, 1933, p. 9).

grease can be detected by placing the garment between several layers of tissue paper or blotting paper and ironing with a hot iron. The best solvent for oil and grease is ether or petroleum spirit, but if paraffin oil (kerosene) is suspected petroleum spirit should not be used, as it may, and frequently does, contain a little paraffin oil, and in such cases ether should be employed.

Shot Marks. The chemical examination of shot marks on clothing occasionally may prove of value, thus black powder fired at short range leaves an alkaline residue in the cloth that may give the reactions for potassium and sulphide (or sulphate if the sulphide has become oxidized) and possibly for nitrate. Alkalinity and sulphide (or sulphate) generally indicate black powder though sometimes alkaline substances may be mixed with smokeless powder, but potassium is not present always even with black powder, since this is made sometimes with sodium nitrate and not potassium nitrate [1] and it may be present with certain smokeless powders, some of which contain potassium nitrate. Nitrate is found only when the combustion of the powder is incomplete. Lead is often present round the edges of the hole or holes when small shot, slugs or uncoated lead bullets have been used.[2] The total amount of material available for testing is so small that the tests are of necessity micro-chemical or spectroscopic. In order to make the chemical tests, small portions of the cloth round the hole are cut out [3] (without destroying the hole), soaked in distilled water and tested. For the spectroscopic test the portion of cloth cut out is ignited and the ash tested. Control tests should be made on the cloth away from the holes. Schirm and Wester report [4] that potassium, lead, mercury and sulphate were all identified in a shot mark, the mercury being derived from the fulminate of the cap. The potassium was detected both by platinic chloride and also by cobalt nitrite ; the lead was detected by the formation of the triple nitrite of lead, copper and potassium, and the mercury by the formation of the double sulphocyanate of mercury and cobalt.[5] A proposed method for the detection on clothing of metallic traces resulting from shooting has been published.[6]

Sometimes a shot mark or shot hole in clothing is surrounded by a narrow black zone, which may be due to smoke, powder residues, or to dirt or grease

[1] See p. 181.

[2] Walker, J. T., " Bullet Holes and Chemical Residues in Shooting Cases," *J. Criminal Law and Criminology*, **31** (1940), pp. 507–509.

[3] See footnote, p. 29.

[4] A. H. Schirm and D. H. Wester, " Chemico-forensic Investigations," *Ber. pharm. Ges.*, **28**, pp. 127–37 (1918), *Chemical Abstracts*, **14** (1920), p. 390.

[5] See also C. Newcomb, " Identification of Gunpowder Carbon in the Tissues," *Annual Report of the Chemical Examiner for the Year* 1934, *Government of Madras* ; *Analyst*, **60** (1935), p. 761.

[6] A. Bruning and M. Schnetka, *Chem. Ztg.*, 1937, **61**, pp. 827–828, and *Analyst*, **62** (1937), pp. 891–892.

from the projectile. Grease may be identified by covering the area immediately round the hole with several layers of tissue paper and pressing with a hot iron, which will transfer part of any grease present to the paper. It should be remembered, however, that wax gives a similar stain to grease. The presence of such a stain is an indication that should be interpretated with the greatest caution, as it may be due to any one of several causes, each indicating a different type of cartridge, namely to a lubricant on the exposed surface of a bullet; to beeswax or other wax or grease in the cannelure (groove round a bullet near the base) of a bullet; to a greased or waxed wad; to a solid wad of wax [1] or to greased or waxed paper that sometimes is wrapped round the base of a bullet. That cartridges possessing such features may be obsolete and made no longer does not prevent their occasional use, as was proved in the Browne and Kennedy murder case,[2] and in Egypt, only a few years ago, some of the earliest type of muzzle-loading cartridges ever made (probably more than sixty years old) were seized by the police and submitted for examination.

Vomit Stains. Stains of vomit, also of fæces and urine, on clothing or bed clothes frequently are of importance in cases of poisoning or suspected poisoning and should be examined, the nature of the examination being indicated by the kind of poison suspected to be present. In the Pritchard case, antimony was found in stains on a chemise, on two sheets and on a toilet cover,[3] and in the Chantrelle case opium was found in stains on a sheet and on a bed gown.[4]

Miscellaneous Stains. These include stains caused by chemicals (other than acids, which have been dealt with), dye, fruit juice, paint, rust, ink, wine and many other substances, each requiring a different method of treatment, which frequently is indicated by the appearance of the stain. As already mentioned, small portions of the stained area should be cut out,[5] the stain dissolved off [6] and the solution tested. Water is the best general solvent and should be tried first and then alcohol, ether and petroleum spirit (petrol) in the order named, the cloth being dried carefully and slowly before a fresh solvent is applied. Fruit stains frequently change colour on the addition of ammonia to the solution; rust stains are soluble in dilute hydrochloric acid and may be tested by means of potassium ferrocyanide or potassium thiocyanate; ink stains, where the ink is the ordinary blue-black writing fluid, turn blue on the addition of hydrochloric acid, oxalic acid or citric acid, owing to the decolorization of the iron compound and

[1] A thick wad of solid paraffin wax was found on one occasion in a rifle cartridge.
[2] W. T. Shore, *Trial of Browne and Kennedy*, 1930, pp. 105–6.
[3] W. Roughead, *Trial of Dr. Pritchard*, 1906, p. 165.
[4] A. D. Smith, *Trial of E. M. Chantrelle*, 1906, pp. 220–1; 224–5.
[5] See footnote, p. 29. [6] See p. 51.

the unmasking of the blue colour present. This blue, which is generally an aniline dye, may be decolorized by means of a solution of bleaching powder or of sodium hypochlorite. Many aniline dye stains are soluble in alcohol and the colour, like that of the blue of ink, is discharged by bleaching powder or by sodium hypochlorite. Stains of silver nitrate are soluble in potassium cyanide, and the presence of silver may be proved by electrolyzing the solution (using a copper electrode), dissolving off the deposited silver with dilute nitric acid and testing in the usual manner. Paint stains often are soluble in turpentine. A spectroscopic examination of the ash of stained cloth may give valuable information.

Dust and Dirt. To remove dust and dirt from a garment for the purpose of examination, a miniature vacuum cleaner will be found satisfactory, provided that it can be taken entirely to pieces and thoroughly cleaned between each operation, otherwise contamination with the dust from previous use must occur and misleading indications will be obtained. In a case mentioned by Hans Gross,[1] a coat from which it was desired to examine the dust was placed in a strong paper bag, which was beaten with a stick and the dust thus collected.

The dust and dirt from pockets should always be examined. As a rule the best way of obtaining it is to remove the pockets bodily (either by unstitching or cutting), to cut the stitches at the seam and to open out the pocket on a large sheet of paper spread on a table and collect the dust by means of a small new, clean brush. The dirt, too, on boots and shoes may be significant and often repays examination. Usually this is best removed, not by scraping as often is advocated, which may break up fragile material such as leaf tissue, but by means of water and a soft brush. As differences in the colour or nature of the dirt sometimes can be seen best when dry, the dirt should be examined carefully with a lens before wetting and removal and, if the boots or shoes are wet, it is usually better to allow them to dry before the examination is made, even though they will be wetted again later. Each boot or shoe should be placed separately in a white porcelain photographic dish while the dirt is being removed. If layers or patches of different kinds or colours of material are seen, these should be separated and examined apart. The methods of examining dust and dirt will be dealt with later.[2]

State of Preservation of Clothing. The state of preservation of clothes that have been buried may have an important bearing upon the estimation of the length of time that has elapsed since burial, and hence may be of value in connexion with crimes of murder in which the body has been buried. The extent of the preservation in such cases depends,

[1] Hans Gross, *Criminal Investigation*, 1934, p. 144.

[2] See pp. 135–136.

not only upon the nature of the material, whether for example it is linen, cotton, wool or silk, but also upon the nature of the soil and the depth at which burial has been made, dampness, which varies with the depth, being one of the most important factors leading to decay and no general rule can be stated.[1] Thus linen cloth from Egyptian rock-cut tombs several thousands of years old is generally still in excellent condition in those cases in which the tomb has been dry, while in other instances in which moisture has penetrated it may be very friable or may have perished entirely.

Occasionally the age of clothes may be of importance and this may be judged to some extent from their condition as regards wear and tear and dirt and also from their colour, for example whether fresh or faded. In the East, where coloured clothes often fade by exposure to the sun and where washable clothes are much worn during hot weather, both fading and washing may be significant. Fading, if present, is self-evident and the colour of the outside only need be compared with that of the inside or that under a turned-over edge for any difference to be seen. Washing may be of importance either in connexion with the possible removal of stains or in respect to shrinkage. Thus in once case the clothes worn by a person who wounded another by shooting, were described by the wounded man as being of khaki and small and tight. A suspected individual was found wearing such a suit : he attributed the tightness to shrinkage during washing, the date of which could not be proved, but which he stated was subsequent to that of the crime. The clothes when examined by me were found to have been washed but, since the date of washing was not certain, nothing could be done, though if they had not been washed the defence set up would have been untenable. As evidence of washing the loss of the harsh feeling of new cloth, the rusting of metal buttons or of metal shanks of buttons, the running of colour on to the adjoining cloth, and the characteristic frayed appearance of free edges at seams caused by washing may all be of importance.

Dyeing of Clothing. The colour of clothes, and whether or not they have been dyed subsequent to making, may sometimes be of importance. Thus, in a certain murder case, the wife of the murdered man, who had been with him when he was shot, stated that the murderer was wearing a light-grey coloured suit which had a zig-zag pattern. As the result of my examination of a coat and trousers belonging to one of the suspects I was able to state in evidence that both coat and trousers originally had been a grey colour with a well marked zig-zag pattern running horizontally across the cloth and that they had been dyed a navy-blue colour since they were made. The original colour of the cloth could be seen in certain small areas when the seams at the bottom of the trouser legs were unstitched

[1] See Illustrative Case No. 2, pp. 59–60.

and the zig-zag pattern was still faintly visible under the dye. The dyeing was proved by the facts that the main lining of the coat, the lining of the sleeves, the strip of lining round the top of the trousers, the material of all the pockets in both coat and trousers and the thread used for stitching were all of the same blue colour and that underneath the dye of the coat sleeves and that of the lining at the top of the trousers an original striped pattern, such as is very common in material used for lining, could be seen faintly.

In connexion with dyes it may be mentioned that differences between various dyes that appear the same in ordinary light sometimes may be detected by photographing them with infra-red sensitive plates.[1]

Burnt Cloth. Laudermilk states that in certain cases the nature of cloth may be determined from a chemical and microscopical examination of the ash.[2]

Illustrative Cases. 1. A waistcoat was submitted with a request that it might be examined for clues concerning the immediate history of the owner, who was discovered under suspicious circumstances near the Suez Canal during the war of 1914-18. The following significant facts were found:

The waistcoat was clean, in good condition, and looked almost new.

The bone button of an inner pocket bore a name that was probably that of the tailor and the address Batavia.

A piece of lining at one of the armholes bore a portion only of a stain (manifestly due to perspiration) that ceased abruptly at a seam where two separate pieces of the lining were joined and was not present on the other side of the seam, but was continued on the turned-down edge where the first piece of material was folded in order to sew it to the second.

The waistcoat was impregnated, both at the top and bottom, with chlorides, sulphates and compounds of calcium, magnesium, sodium and potassium,[3] the salts characteristic of sea water, and the magnesia was present in greater proportion than the lime, which is also a characteristic of sea water. It should not be forgotten, however, that these same salts occur in the sand of the seashore, in the dust on any roads near the sea, and even in the sea air. They are found also in the dust of the desert, and hence on clothes that have been worn in the desert, and chlorides might be derived from perspiration. Traces of bromide may be of significance as indicating sea water.

[1] P. W. Cunliffe, "Application of Infra-Red Photography to Textiles," *J. Soc. Dyers and Col.*, **49** (1933), p. 73 (*Analyst*, **58** (1933), p. 308).

[2] J. D. Laudermilk, "Identification of Cloth Ash," *The Journal of Criminal Law and Criminology*, **24** (1933), pp. 503–16.

[3] These naturally were not visible, but portions of the waistcoat were soaked in distilled water, and the solutions thus obtained were examined chemically

Each pocket contained a small amount of very fine quartz sand with rounded grains of the usual size of dune sand, namely varying from about 0·1 millimetre to about 0·5 millimetre in diameter.

The deductions from the above facts were as follows :

The owner of the waistcoat had bought a ready-made suit of clothes in Batavia. The stain proved that the lining had been used before, since evidently it had not been acquired while the lining was in its existing position, and the fact of the waistcoat being almost new pointed to a cheap ready-made suit in which some old lining had been used, rather than to second-hand clothes.

The man had travelled to Egypt in a Dutch steamer, since Dutch steamers were then passing through the Suez Canal and were the only ones that called at Batavia.

The man had left the steamer surreptitiously while it was passing through the Canal and had swum to the shore. Entire submersion, pointing to swimming, was indicated by the fact that even the top of the waistcoat showed evidence of having been wetted with salt water, and it followed therefore that the mode of leaving the steamer was unusual and probably surreptitious.

The man had landed from the Canal at a place where there were sand dunes. This was indicated by the nature of the sand found in the pockets.

The above conclusions were proved subsequently to be correct.

2. The remains of a man in European clothing were found buried on some unoccupied land, and it was hoped that some clue to his identity might be discovered from an examination of the clothes. The following facts were noted :

The coat and waistcoat were alike and were of thick striped brown tweed. Parts of some bone buttons still remained, but these did not bear any tailor's name or other description.

The trousers did not match the coat and waistcoat, but were of thinner material, though almost of the same colour and pattern. There were six metal buttons left on the trousers, all of which were very corroded but, when cleaned, the name and address of a tailor in Duke Street, Portland Place, London, were legible.

Most of the stitching of the clothes had perished, leaving the garments in separate pieces : the lining was much decayed and the pockets were missing.

The undervest, of which only a part remained, was of cotton.

The shirt, of which only a part remained, was of coloured cotton, the predominant colour being green, but there were brown stripes that probably had been red originally. The front was pleated and was ornamented with cross stitches in red.

The one sock was of thick red wool and in fairly good condition.

There was a part of a good quality handkerchief, that, however, bore no name.

Collar, boots, and hat were missing, but no very careful search had been made for these or other articles.

This case is recorded on account of one very interesting feature, namely that the articles made of cotton, such as the shirt and vest, the lining of the clothes and the thread used for stitching, had perished to a much greater extent than the articles composed of wool, like the clothes and the sock.

3. An Egyptian dressed in European clothes, who had been killed by having his throat cut, was found in a garden. Round his neck there was tied a *gallabia*,[1] probably to soak up the blood, and lying near the body was a small piece that had been torn from the *gallabia*, on which, in addition to blood stains, were black smears, marks of yellow material, much blackened, and patches of white metal in very thin layers. Analysis proved the black material to be carbon, the yellow to be resin blackened by carbon, and the metal to be plumber's solder. The small piece of material therefore had been used by a plumber for " wiping " a joint, and thus a valuable clue was afforded for the police to follow up.

There were also other clues ; thus the pattern on the *gallabia* consisted of circles, indicating that the garment had belonged to a woman or girl, since men's *gallabias* are plain or striped and never have patterns of circles, spots or flowers,[2] while women's *gallabias*, unless plain, possess these patterns and are seldom, if ever, striped. The *gallabia* had also a pleat down each side of the upper part of the front, which again indicated a woman's or child's dress, and was very much torn at the front and had a patch of different material inserted from inside in order to mend one of the torn places.

4. A policeman who witnessed the explosion of a bomb and gave chase to the thrower was shot at twice by this individual, and was found to be wounded slightly in several places, and it was desired to know whether the wounds were caused by the explosion or by the shots. His clothes were examined, and in the tunic, which was of white drill, there were several holes, the edges of some of which were stained with a yellow substance that on testing was found to be picric acid, thus proving that the wounds had been caused by fragments of the bomb. In this same case the man who threw the bomb was also wounded by the explosion and there was a stain of picric acid on the torn edge of a small hole in the cuff of his shirt.

[1] Loose outer garment worn by both men and women of the poorer classes in Egypt.

[2] The author has only seen one exception, which was that of a *gallabia* worn by a boy, that had a pattern consisting of ovals.

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CHAPTER IV

COUNTERFEIT COINS

THE examination of counterfeit coins, although not wholly chemical, has an important chemical aspect, as generally it is necessary to determine the weight, specific gravity and composition of the suspected coins.

Counterfeit coins are essentially of two kinds, cast and struck, the former being made in moulds and the latter by means of dies. There is, however, a third way in which counterfeit coins might be made, namely by means of the electrotype process, a method frequently employed for reproducing rare coins for museum purposes, but which is seldom, if ever, used by false coiners.

Since gold has practically disappeared from circulation, counterfeit gold coins are made no longer and so need only a passing mention. One great difficulty in making such coins successfully is the weight, gold being one of the heaviest of the metals and almost twice as heavy as lead. Platinum, however, which is somewhat heavier than gold and which at one time was the cheaper of the two, although now much dearer, has been gilded and employed occasionally in the past to counterfeit gold. In one case in Egypt, counterfeit English sovereigns were cast in lead and gilded, but the imitation was very crude. There have been several instances, too, in Egypt, in which the imitation sovereigns made in England and sold at one time in the streets of London at a penny each were passed as genuine coins. These were of the same size as a sovereign, though much lighter in weight, and were of copper gilt and, since they were struck and not cast, the design was good and sharp; they were also milled. These imitation coins were provided with a small ring at the top that was removed easily, though evidence of it was left.

For obvious reason, any detailed description of the manner in which counterfeit coins are made will be omitted, though a few general indications may be given.

Cast coins are made in one operation by casting the metal in moulds prepared by taking impressions of genuine coins in suitable material such as plaster of paris, clay, moulding sand or sometimes bronze. The "runner"[1] is removed and the edge of the coin touched up with a file. Cast coins are generally much poorer imitations than those that are struck,

[1] The thin rod remaining attached to the coin where the metal has entered the mould. Any vents made for the escape of air would produce similar, though thinner rods, but although I have examined a very large number of coinage moulds, I have never yet seen any provided with special air vents, the imperfect fitting of the separate parts of the mould supplying sufficient outlet for the air.

and hence are detected more easily. A really first class casting, however, with good milling, which fortunately is very rare, is most difficult to detect, especially if worn, since even the smallest details of the design are correct. The surface of a cast coin is frequently pitted and uneven, the edges of the lettering and design are rounded instead of being sharp, there are small projections of metal where the lines should be straight and, in that section of the circumference from which the " runner " has been removed, the milling is often irregular or defective and shows evidence of having been made or adjusted with a file. Sometimes, however, the runner is so skilfully taken off and the milling so cleverly adjusted that, if the casting has been well done, it is difficult to say whether the coin has been cast or struck.

A certain proportion of the counterfeit coins made in Egypt are struck and many are excellent imitations. To make struck coins at least two separate operations are required, first the punching of circular pieces of metal of the correct size and weight from a sheet or strip, and second the impressing on these " blanks " the design of the coin. This latter is done from dies, the force being produced by means of a press. Generally, in order to obtain the milling, a steel collar, that is milled inside, fits round the dies, though sometimes other devices are employed, such as pressing the blanks against milled wheels.

The dies, which are of steel, usually are engraved, but may be cast and then touched up by an engraver. In the case of engraved dies, which necessarily take considerable time and skill to prepare, the counterfeiter sometimes follows the practice of the mints and only employs the original dies as a means of obtaining secondary dies, and it is these latter, that can be duplicated readily when broken or worn, that are used for striking the coins. These secondary dies naturally all exhibit the same features, any slight peculiarity or defect existing in the originals being reproduced in the copies.

Struck counterfeit coins are often very well executed, and their detection is not always an easy matter, but one requiring considerable experience, since the weight, size, specific gravity, milling and composition may all be good, and only a careful comparison of the smaller details of the design with those of a genuine coin enables the deception to be discovered. A counterfeit coin is less easily detected when it is worn than when freshly made.

Photographic enlargements of counterfeit coins are very helpful for attaching to the report, or for presentation in Court, as they enable similarities or differences between various coins to be demonstrated readily. Special methods for use when photographing coins are described in the chapter on Photography.[1]

[1] See pp. 248–250.

Sometimes it is useful to mark on a map the places where particular kinds of coins have been passed, with the number of coins from each place, as this may show the centre of distribution and so indicate a particular district in which special search should be made.

The services of a chemist are required not only for the examination of counterfeit coins, but also for the analysis of the materials seized on the premises of suspected persons, which may include metals, moulding composition and miscellaneous chemicals and sometimes an ingot or other piece of metal or a little fused metal left in a crucible can be proved to be identical in composition with certain counterfeit coins seized.

Since the chemist is consulted about so many aspects of the question, his opinion may be asked about the use of various apparatus and appliances used in making counterfeit coins, such as crucibles, casting frames, moulds, flattening mills, punches, punching machines, dies and presses. Frequently such apparatus is very primitive, though occasionally it is complete and ingenious. Naturally no details or descriptions can be given.

The expert to whom questions in connexion with counterfeit coining are referred should familiarize himself with the methods used in the minting of genuine coins.

Most cases of counterfeit coining are devoid of any special interest, apart from the ingenuity displayed in adapting primitive apparatus and appliances intended for other purposes to the needs of the coiner. In one important coining case, in which a large number of persons were condemned, considerable use was made of small portable punching machines such as are used for punching holes in iron plates, these being not only employed for preparing the blanks, but also being fitted with dies and used as presses, although not very suitable for this latter purpose.

Method of Examination. The most important points to which attention should be directed when examining suspected coins are first, the details of the design and the manner in which this has been executed, that is to say the quality of the workmanship, and second, the milling, and unless the counterfeit is very poor, a careful inspection with a lens, or preferably with a stereoscopic microscope and low magnification, and a careful comparison with a genuine coin are essential. In a genuine coin the milling is regular and at right angles to the face of the coin, while in counterfeit coins it is often irregular and slanting. In cast coins there is sometimes a fault down the middle of the milling, showing that the two halves of the mould have not fitted well together.

The examination of the milling of a coin should include the determination of the number of ridges. This can be done by colouring the edge of the coin by means of a pad moistened with aniline ink, carefully removing the

colour from one of the ridges, and then taking the impression of the circumference of the coin on paper, and counting the number of lines made by the ridges, using the blank spaces caused by the removal of the colour from one of the ridges as the starting and finishing points, the number of ridges on the coin being of course the number of lines counted plus one. It should not be forgotten, however, that the diameter of genuine coins, and hence the number of ridges, may vary with different issues of coins of the same denomination from the same mint, and that the number of ridges may also vary with coins of the same denomination from different mints although the diameter of the coins may be the same. Counterfeit coins made with the same dies also may have different milling owing to the use of different milling collars or wheels. The milling of a genuine but cracked coin is often found damaged on account of the coin having been thrown repeatedly on to a hard surface to test the ring.

The beading on the inner side of the rim of a coin also should be carefully examined since in a counterfeit coin the beads are often not uniform in size and are shaped badly and spaced irregularly instead of being uniform and equidistant from one another. The colour of a coin is often an indication of its genuineness or otherwise, a yellowish or leaden colour, for example, in a silver coin often being a sign that the coin is counterfeit.

Both the weight and specific gravity of suspected coins are useful indications, especially the latter, and should always be determined, the weight of course necessarily being ascertained when taking the specific gravity.[1] Any marked excess of weight above the legal limits is a certain proof that the coin is counterfeit; a deficiency in weight may be due to the coin being worn.

The density of coins composed of the same alloy and from the same mint is only constant for coins of the same size, and it varies inversely as the size of the coin, the smaller the coin, the greater being the density, the reason being that the blow required for impressing the design on the coin acts on a smaller area and on a thinner piece of metal in the case of the smaller coins, and hence produces a greater effect.

The determination of the hardness of a coin, although possibly of some use to the person who tests a coin by biting it, is not of much assistance in any scientific examination.

The " ring " of a coin also is of very little value, since many counterfeit coins ring well, while genuine coins, if cracked, ring badly.

Sometimes genuine coins that have been subjected to the action of chemicals or fire or that have been run over by a heavy vehicle or that

[1] For the determination of the specific gravity a little basket made from fine platinum wire in which to suspend the coin when weighing it in water will be found useful.

have been bored and the hole subsequently filled up, or that have been fitted with a ring for suspension, which has been removed and the milling adjusted with a file, are submitted to the expert because of their suspicious appearance, but such cases rarely present any real difficulty.

Sometimes secret marks are placed on coins by the mint, and unless a coin is worn their absence is a certain proof that the coin is counterfeit. Too much reliance, however, should not be placed upon the presence of secret marks, since they are reproduced on cast coins. Such marks never act as deterrents against forgery.

Counterfeit coins should be examined carefully for slight flaws and marks, since these if present on a number of different coins prove that all have been made in the same mould or with the same dies, or with dies made from the same punch or matrix, and so may enable the police to trace coins passed in different places to one central factory. This has been helpful on many occasions. Thus in several cases it has been possible to trace cast coins seized with different persons to the same source because all the coins had the same defects and manifestly had been made in the same mould. In one important coining case that had ramifications in different parts of the country and in connexion with which about forty persons were condemned, struck coins from places far apart all bore evidence in the details of the design, that they had been made either from the same dies or from dies made from the same punch or matrix and in many instances they had certainly been made from the same dies, since a flaw due to a crack in one of the dies occurred in the same position on each of the coins. A method of classifying coins for purposes of comparison has been published.[1]

Coins made even with the same dies may exhibit occasionally slight differences due to a different manner of striking or to the dies or blanks not having been rigid during striking.

Chemical Analysis. A qualitative analysis of counterfeit coins is required practically always, as it is generally necessary to state in the report of what metal or metals the coins consist. A quantitative analysis, however, is frequently not absolutely necessary, though it is always useful, and should be made whenever possible, but it becomes essential when the composition of the coins has to be compared with that of metal found on the premises of a suspected person.[2]

No general scheme of analysis applicable to all cases can be laid down, as the methods adopted depend upon the nature of the alloy and vary considerably in the presence of certain metals such as silver and antimony. The methods, however, are all standard ones that may be found described

[1] A. Popkess, " Classification of Handwriting and Counterfeit Coins," *The Police Journal*, 7 (1934), pp. 270–2.

[2] See Illustrative Case No. 1.

in the text books. The usual constituents of counterfeit coins are one or more of the following, namely antimony, copper, lead, silver, tin and zinc.

Sometimes counterfeit coins are of the same composition as genuine coins, and several instances of this occurred in Egypt before the war, when the price of silver was low.

Illustrative Cases. 1. As possible connecting links between counterfeit coins and a suspected person, several pieces of white metal, and some similar looking metal adhering to the end of an iron rod, that manifestly had been used as a stirrer, were examined. The defence set up was that these articles had no connexion with counterfeit coining but had been used for tinning copper saucepans, a common practice in Egypt. Analysis, however, proved that the pieces of metal and the metal on the rod were identical in composition with the counterfeit coins and differed considerably from the material ordinarily employed for tinning saucepans and the man was convicted.

2. This was a case of English sovereigns that had been sweated, in some instances having been reduced as much as half a gram each in weight. Examination proved that the faces of the coins had been protected, probably by grease or wax, and the edges then sweated by means of aqua regia, since traces of both nitrate and chloride were found on the coins.

3. Among a number of articles seized in one case were a small cylindrical piece of wood and a hammer. One end of the wood had the appearance of having been struck repeatedly and on the other end there were impressions of parts of the design of a coin and also tiny particles of white metal, which on analysis proved to be largely silver, and wood fibres were found in a depression on the head of the hammer. Manifestly, therefore, both the wood and hammer had been employed together in some connexion with silver coins and it was confessed afterwards that they had been used to force counterfeit coins out of the milling collar. A similar piece of wood, also bearing the impressions of parts of the design of a coin, and adhering to which were tiny particles of white metal too small to allow of analysis, was found subsequently in another case.

4. In other cases impressions of coins on metal (lead, copper and iron) have been found and in some instances it has been possible to state that the impressions had been made with counterfeit coins. In one instance a large number of circular impressions the size of one of the Egyptian silver coins were found on two blocks of wood that had been used as a support for a press and on several of these impressions there were parts of the design of a coin. Although the presence of the press, which was without dies, was suspicious in itself, it was not sufficient to connect the man on whose premises it was found with counterfeit coining, since it was possible

that such a press might have been used for legitimate purposes, but the impressions of the coins on the wooden base placed it beyond doubt that it had been employed for making counterfeit coins. In another instance, from the marks left on the wooden parts of an apparatus that had been employed for putting the milling on counterfeit coins it was possible to prove, not only the size of the coins, but that the instrument had been much used.

5. In various other cases small amounts of moulding composition (sand, clay, plaster of paris) found in brass and iron casting frames proved that these had been used and in a few instances where the moulding composition was intact and bore impressions of coins, it was possible to state that certain coins found on the premises had been made in those particular moulds.

In some cases from the presence or absence of rust it has been possible to say whether certain machines and dies used for making counterfeit coins had been employed recently or not and in one case, from some splashes of colour wash on the iron base of a press, it was possible to place a limit to the time since this had been used, as the date when the premises were colour-washed last was known.

6. A minute fragment of metal, from which the test for copper was obtained, but which was too small for the reactions for other metals to be observed, though judging from its colour the metal was not wholly copper, was found on a file seized in the house of a person suspected of making counterfeit coins, the coins in question being composed of copper and tin.

7. A man was arrested for passing counterfeit coins and when his house was searched very suspicious looking coins representing a value of about £58 were seized. On examination it was found that although many of the coins were discoloured, others deeply scratched and a few badly pitted, all were genuine. A little coarse sand was found adhering to some of the coins. The explanation was that the coins having been hoarded had become discoloured and the owner, an uneducated man, had tried to clean them by vigorous rubbing with coarse sand aided in a few instances by acid.

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CHAPTER V

DOCUMENTS

At first thought it might appear that the examination of documents was hardly within the province of the chemist, but when it is considered that a chemical and microscopical examination of the paper, a chemical analysis of the ink and a chemical examination of any discoloration or stains present, are frequently necessary, it will be recognized that there is a large amount of purely chemical work in this connexion. There are, of course, other aspects that are in no way chemical, such as that of the identity or non-identity of different specimens of handwriting, but since the chemical side is so important, it is not unreasonable that the whole subject should be entrusted to a chemist who has specialized in such matters. In any case, however, the expert undertaking this work should possess some chemical knowledge, should have considerable experience in the use of the microscope, and should be an expert photographer.

Care of Documents. It cannot be insisted upon too strongly that suspected documents are precious things and that therefore they should be treated accordingly. As an example of the lack of care sometimes bestowed upon documents it may be mentioned that on one occasion when dealing with an anonymous letter the mode of formation of the capital *I*, and whether it was made with one stroke of the pen or with two strokes, was of considerable importance and this letter only occurred twice and one of the two occurrences had been mutilated by the document having been perforated by filing. Also, it is a very common practice to fasten several documents together by means of a pin instead of with a paper clip, and repeated pinning may, and often does, obliterate important features of the writing, especially writing on the back of any of the documents, and on more than one occasion in my experience endorsements on cheques and on postal orders have been defaced in this manner. Also, amateur handwriting enthusiasts not infrequently place thick lines, generally with ink, or coloured pencil, round, or under, certain characteristic features, to which they wish to draw attention, and these lines may touch and obscure important details of the writing. Even the professional handwriting expert sometimes defaces the documents submitted to him for examination by placing tiny arrows in red ink against important features. If any marking is thought to be necessary, it should always be done on photographs and never on original documents.

Documents that are to be examined by the expert should be handled, folded and marked as little as possible.

On receipt, all documents should be placed without folding, even though they may have been folded previously, between plain white paper in a cardboard cover. The examination should be made on a clean table on which there should not be any bottles containing ink, liquids or chemicals that could soil or damage the document if accidentally upset and even the reagents used for testing purposes should be placed elsewhere. Documents should not be touched with pen, pencil or anything that could possibly mark them and should be handled as little as possible. In most cases it is advisable to photograph a document before examination, in order to have a record of its exact condition on receipt in case there should be any subsequent question or dispute, but this is not always practicable, especially if a large number of documents are received together. For photographic purposes the document should not be pinned or nailed, but should be placed on a piece of cardboard and covered with a sheet of glass of good quality and without colour or flaws and should be held in position in an adjustable wooden frame.

Preliminary Examination. A careful scrutiny is first made of the document as a whole in the usual way by reflected light, afterwards by transmitted light and finally by ultra-violet rays, both sides of the paper being inspected. The document is then examined in detail with a lens and any doubtful portions examined further with a microscope, special search being made for evidence of alterations and erasures if these are suspected. In some cases the nature of the material of which the paper is made must be determined, and for this purpose a very small piece is cut from one corner. Generally, too, the ink should be analysed and the handwriting examined critically. Frequently an enlarged photograph will be found helpful, especially in cases of alteration or erasure or when a comparison of the handwriting with that of another document is required.

Paper.

One of the earliest substances used for writing upon was Egyptian papyrus, the pith of which was sliced into layers that were beaten and pressed together into sheets and it is from the name " papyrus " that the word " paper " is derived. After papyrus came parchment and vellum, which are still used for many legal documents, the former being made from the skins of sheep and goats and the latter from the more delicate skins of calves and kids. Parchment and vellum were succeeded by rags, at first linen rags, and afterwards a mixture of linen and cotton, or cotton only. A letter dated A.D. 874, and documents that from internal evidence are believed to belong to the year A.D. 792, made of linen, were found some years ago in the Fayum province in Egypt.[1] The date of the oldest manuscript in England on cotton paper

[1] R. W. Sindall, *The Manufacture of Paper*, 1908, p. 6.

is stated to be 1049.[1] Although experiments in paper making were made with a great variety of fibrous materials, rags were generally employed until about the middle of the nineteenth century. Straw was first used in 1800, a book made from it being published in England at that date,[2] though it was not employed on a large scale until more than fifty years afterwards. The manufacture of paper from mechanical wood pulp is subsequent to 1869[2]; from soda wood pulp between 1845 and 1880,[2] and from sulphite wood pulp between 1880 and 1890,[2] though apparently trials were made at an earlier date, as it is stated that a patent was granted in Italy in 1826 for the use of wood pulp.[3] The general use of mechanical wood pulp, however, dates from 1870–80 and that of chemical wood pulp from 1880–90.[4] Esparto was introduced into England subsequent to 1861.[2] Before 1798 all paper was hand made, but in that year the first paper machine was invented in France, and in 1809 a paper machine was erected in England.[5] Blotting paper is mentioned as early as 1465 and fragments have been found in fifteenth-century account books and in the sixteenth century it is referred to as though it were well known,[6] though it was not in general use until the beginning of the nineteenth century, a fine powder, such as sand, being employed instead, and even to-day sand is used occasionally for this purpose in Egypt. Brown paper is referred to in 1570–1.[6]

Four cases in which the composition of paper has been of importance may be mentioned. In one instance a document dated 1213 A.H. (A.D. 1798) was composed entirely of chemically prepared wood cellulose, although this material was not employed for paper making until more than sixty years afterwards; in another case it proved a useful point in favour of the accused that paper found in his house, which resembled superficially that of some anonymous correspondence, and was stated by one self-styled expert (who, however, had not examined it microscopically) to be the same, was of entirely different composition; and in other cases the paper of an anonymous letter and of forged certificates respectively was traced to particular sources. In this connexion it may be mentioned that a number of old Arabic documents, mostly title-deeds of land dating between 1136 A.H. (A.D. 1723) and 1287 A.H. (A.D. 1870), examined by me were found to be composed entirely of linen, as was also the paper of two old account books in Arabic, one dated 1181 A.H. (A.D. 1767) and the other 1216 A.H. to 1218 A.H. (A.D. 1801 to 1803). The paper of three manuscript Coptic religious books I examined was also of linen. These were (*a*) a portion of the Old Testament written in Arabic

[1] R. W. Sindall, *Paper Technology*, 1906, pp. 208, 209.
[2] J. Grant, *Books and Documents*, pp. 15–16.
[3] *Chambers's Encyclopædia*, 7, 1908.
[4] Society of Arts, *Deterioration of Paper*. London, 1898.
[5] J. Grant, *op. cit.*, p. 6.
[6] Article "Paper" in *Encyclopædia Britannica*, 11th ed., 1911.

and bearing the Coptic date 1028 (A.D. 1312); (*b*) a large prayer book in both Coptic and Arabic, undated, but manifestly old, and (*c*) a small prayer book in both Coptic and Arabic, also undated but old.

Water-mark. Sometimes a limit may be placed to the age of a document by means of a water-mark, the earliest known dating from 1282.[1] A dated water-mark, however, should not be taken as an infallible proof of age, thus in 1921 a well-known German firm of scientific instrument makers was using a paper bearing a water-mark dated 1875.

In an important case in which the title to a large area of land was in dispute certain receipts were produced dated 1294, 1295, 1296 and 1297 A.H. respectively (A.D. 1876, 1877, 1878 and 1879), all of which bore the Egyptian Government water-mark although this was not introduced until some years later.[2] In the same case two other receipts dated three months apart originally had formed part of the same sheet of paper and a portion of the same water-mark appeared on each and it seemed improbable that part of a sheet of paper should be used on one occasion and the other part not until three months later. In another case a number of receipts, the dates of which extended over a period of a year and ten months, were all parts of similar sheets of foolscap, which after considerable trouble it was found possible to fit together. It was then seen that the order in which the pieces occurred did not correspond with the dates on the receipts, thus for example a receipt dated January of one year was part of the same sheet as a receipt dated January of the following year, while parts of other sheets, in no regular order, had been used for intermediate dates. This at once raised a presumption of forgery, since it seemed improbable that one part of a sheet of paper should be used one year and a second part not until twelve months afterwards, although meanwhile other sheets had been torn up and used for a similar purpose. The water-mark on the paper was very helpful in fitting the various pieces together. In connexion with a forgery case the fact that blank sheets of paper found in the houses of two of the accused persons bore an unusual water-mark, that also occurred on some of the forged documents, was a link in the chain of circumstantial evidence that convicted them. Sometimes water-marks are forged on the finished paper by means of a stamp used with wax or an oily medium, which imparts a transparency to that part of the paper where the design appears. Such water-marks can be removed generally by gentle sponging with ether, which treatment therefore is a good test, though if only one water-mark is available naturally it should not all be removed, but only a small part.

[1] J. Grant, *Books and Documents*, pp. 4, 30.

[2] So far as can be ascertained no Egyptian Government paper bore a special Government water-mark before about 1885, but in 1887 a dated water-mark was certainly in use, though at first only on stamped paper. A date was added to the water-mark on the ordinary correspondence paper in 1915.

In one instance in my experience a yellowish oily paste had been used to forge a water-mark on certain banknotes which was not removable by ether. Forged water-marks too often may be detected when exposed to the ultra-violet rays.[1] In one instance recorded the forged water-mark only became visible under the ultra-violet rays after it had been entirely removed apparently by ether.[2]

A series of three crescent moons of different sizes is an old water-mark on paper used in Egypt and certainly occurs as early as 1188 A.H. (A.D. 1774), and it occurs in at least two different forms. Browne mentions[3] *papier de trois lunes* as an article of commerce from Egypt to Darfur in 1806. According to Burckhardt this paper, which he wrongly describes as *papier de trois limes*, was from Genoa and Leghorn.[4] A water-mark of three stars has been noticed on documents dated 1190 A.H. (A.D. 1776).

Testing of Paper. The determination of the nature of the fibre is made by means of the microscope after the paper has been prepared suitably, the different fibres being identified readily by their characteristic appearance and by their colour when treated with certain reagents. The fragment of paper to be examined, which need only be very minute, is torn or cut up, placed in a small beaker and boiled with dilute sodium hydroxide solution (5 per cent.) to disintegrate the fibres and to remove the sizing and loading materials. The liquid is poured off and the paper washed repeatedly with water by decantation. If the sample is large enough, it is then transferred

Fibre.	Iodine (*a*).	Zinc-chlor-iodine (*b*).	Phloro-glucine (*c*).	Aniline (*d*) Sulphate.
Linen . . .	light to dark brown	weak to strong wine-red	nil	nil
Cotton . . .				
Straw . . .	almost colourless to light brown (*e*)	blue	nil	nil (*f*)
Esparto . . .				
Wood (chemical) .				
Wood (mechanical)	yellow to brown	yellow	red (*g*)	yellow

(*a*) Potassium iodide 2 grams : iodine 1·5 grams : glycerine 2 c.c. : water 20 c.c.
(*b*) (1) Zinc chloride 20 grams : water 10 c.c. : (2) potassium iodide 2·1 grams : iodine 0·1 gram : water 5 c.c. Mix (1) and (2) and allow the mixture to stand, and decant off the clear supernatant liquid for use.
(*c*) Phloroglucine 1 gram : water 25 c.c. : hydrochloric acid (conc.) 5 c.c.
(*d*) 10 per cent.
(*e*) As seen in the brown iodine solution.
(*f*) A pink colour develops on heating and varies in intensity with the proportion of straw and esparto present.
(*g*) As certain dyes sometimes present in paper give a red colour with hydrochloric acid, a control experiment with acid alone should be made.

[1] J. Grant, *Analyst*, 59 (1934), pp. 749–50.
[2] J. Grant, *Analyst*, 58 (1933), pp. 603–4.
[3] W. G. Browne, *Travels in Africa, Egypt and Syria*, 2nd ed., 1806.
[4] J. L. Burckhardt, *Travels in Nubia*, 1819, p. 303.

to a small porcelain or glass mortar and broken up thoroughly, dried between filter paper,[1] and small portions picked off with microscope needles, teased out on a slide, stained with iodine, or better with zinc-chlor-iodine solution, and examined microscopically, a magnification of from 300 to 400 diameters being desirable. If the sample is very small, it is transferred, after washing, direct from the beaker to a slide, dried with filter paper,[1] teased out, stained and examined. Several slides should be made from each sample of paper. The various fibres give the results shown in the previous table.[2]

It is important always to employ solutions of the same strength, since variations in the strength of the reagent affect the intensity of the colour produced and the paper should be dry before staining. The staining is not only of use in distinguishing the various kinds of fibre from one another, but also it serves to intensify differences of structure and to bring out details.

Other tests that should be made if the amount of paper available is sufficient are the nature and proportion of the mineral matter present and the nature of the sizing. The former may be determined by incinerating a weighed portion of the paper and analysing the ash, a qualitative examination, as a rule, being sufficient. The usual sizing materials employed for paper are gelatine (animal size), rosin, starch and casein, which may be identified as follows :

Gelatine. This is extracted by boiling the paper in water, the solution obtained being tested by adding a dilute solution of tannic acid, which gives a yellowish [3] precipitate if gelatine is present.

Rosin. This is extracted by heating the paper on the water bath with strong alcohol. The solution obtained is evaporated to dryness and the solid residue dissolved in acetic anhydride, cooled, transferred to a small, flat porcelain dish and tested by adding a drop of strong sulphuric acid, a reddish-violet colour quickly changing to red-brown being produced if rosin is present. A simpler test is to place one or two drops of ether on the paper and if rosin is present a brown ring will be formed when the ether evaporates.

Starch. This may be identified on the paper by means of the blue colour produced by the addition of a very dilute solution of iodine.

Casein. This may be detected by Millon's reagent [4] with which it, in common with other proteins, gives a pink coloration.

[1] Care should be taken that the filter paper has a smooth surface on which there are no loose fibres that might contaminate the sample being tested.

[2] See also Circular C. 423 by T. M. Pitt, *U. S. Dept. of Commerce, National Bureau of Standards*, 1939. *Microscopic Methods used in Identifying Commercial Fibres.* Also *Analyst*, **64** (1939), pp. 425–430.

[3] Starch, if present, is also precipitated by this method, but the precipitate is whitish.

[4] Prepared by dissolving a small quantity of mercury in its own weight of strong nitric acid (sp. gr. 1·4) and then adding twice the volume of water.

Various sizing materials show different colours when exposed to ultra-violet radiation and as a rule any variation of the sizing between different papers, or any patching of the sizing done to hide the removal by erasure of the surface of the paper, is clearly visible.

Discoloration of Documents. Occasionally documents are discoloured intentionally in order to give them a fictitious appearance of age, or they are scorched and partly burned and sometimes creased and torn for a similar reason. These same devices are also used for the purpose of hiding evidence of fraud.

Discoloration due to age is largely a process of oxidation brought about by natural means and it takes place in proportion to the extent to which the paper has been exposed to the air and light and hence the outsides and edges of old documents, which are the most exposed, become the most discoloured, the discoloration diminishing progressively towards the less exposed parts. In addition to the general discoloration, however, there are frequently on old documents brown spots due to mould that are very characteristic both in appearance and distribution. These spots become translucent when wetted with water, regaining their original appearance when dry, the smaller spots as a rule becoming entirely translucent while the larger ones remain opaque at the centre. This is a very simple test and one that may be applied to almost any document without fear of injury. Sometimes isolated brown spots not caused by mould but by iron or other impurities also occur.

Other natural causes for the discoloration of documents are exposure to dust and dirt and occasionally staining by fruit juice, grease and the excreta of rats, mice and insects. In the latter case the outsides and edges of the documents generally suffer the most. Where a document has been discoloured intentionally with dirt, this is evident as a rule by the discoloration showing definite streaks or lines, where the dirt has been rubbed on the paper.

Discoloration may also be due to heat, in which case it is a partial burning of the surface of the paper, which becomes very brittle if the burning is severe, and, unless the paper is thick, when one side becomes scorched the opposite side also shows signs of burning. When a number of documents are exposed to fire while together, those on the outside naturally suffer most and those on the inside may be slightly burned only or not burned at all and any holes produced correspond in relative position in the various documents. The edges of the documents, too, being loose, always burn first. These facts are frequently forgotten by forgers whose handiwork shows a definite selective action that is unnatural, certain documents or parts of documents being burned or spared in a manner that could not possibly be accidental. In one case a piece of blank paper that had been

scorched in the same suspicious manner as some forged documents was found in the house of an accused person.

Artificial discoloration made to simulate age is produced by means of a coloured solution or by exposing the document to the smoke from a wood fire. I have never been able definitely to establish the nature of any solution employed, but in the East coffee is very probable, while in the West tea might be used.[1] A water extract of tobacco or a dilute solution of potassium permanganate also would serve the same purpose. The use of a coloured solution is generally indicated by the characteristic shape of the edges of the discoloured areas, or by the way in which the liquid has run and a thin dark line sometimes occurs where there were any very marked creases on the paper at the time it was treated. Occasionally too portions of the paper, often very small, may be found that have escaped altogether the action of the solution.

Documents Mounted on other Paper. Although documents that have been cut or torn accidentally or worn naturally may be mounted on other paper to strengthen them, this is frequently done when the cutting or tearing has been intentional, or documents may be mounted on other paper to give them a fictitious appearance of age and constant use, to hide signs of erasure or to prevent an examination of the back. When a document mounted on other paper is in several pieces the edges at the joins should be examined carefully, since sometimes these do not correspond, the separate pieces being parts of different documents put together to make a new and fictitious document, or the bottom piece bearing the signature may be part of a genuine document to which writing specially prepared for the purpose has been joined. In other cases the two pieces of paper at a join may overlap and, although a line of writing may be partly on one piece and partly on another, it may not always extend to the edges of both, but only to the edge of the piece that is uppermost, leaving a margin without writing on the under piece, which is proof that the writing was done after the pieces had been joined together. Also sometimes small portions of some of the letters of the writing at a join occur on the paper used for mounting, which again is proof that the mounting paper was in place when the document was written. Sometimes, too, the paper of the separate pieces may be of slightly different quality, width or thickness. Since different papers may vary considerably in appearance when exposed to ultra-violet rays (this usually being due to the different sizing and loading materials employed in their manufacture), an examination by means of ultra-violet rays sometimes may be helpful.

In one case in which a document consisted of two pieces joined together

[1] The use of tea has been recorded by O. A. Mendelsohn. (Artificially Aged Documents, *The Analyst*, 50 (1925), p. 287.)

it was manifest that the paper had been cut and not torn or worn, since not only were marks of short-bladed scissors apparent, but the division was not horizontal across the paper, occurring between two lines of writing and following the very marked slant of the lines.[1] A piece of the document also had been cut away and was missing, since the paper was a laid paper with the usual " water-lines " crossing it horizontally, and where these lines occurred above and below the join they did not coincide. In another case in which a document had been cut accidentally and mounted on other paper, the sequence of the cuts on the one hand and the signature and a registration stamp on the other hand was disputed. That the cuts were later than the signature and stamp was proved by the fact that, although the signature and some writing on the stamp crossed the cuts, there was an entire absence of ink on the cut edges of the paper.

It is a common occurrence in Egypt for old title deeds of land to be written on more than one sheet of paper, the separate sheets being joined end to end ; thus one such document examined was written on nineteen sheets and measured about seven and a half metres in length : sometimes these deeds are twenty or even thirty metres long. Fraud is safeguarded against to some extent by the writing being so arranged that a line crosses each join of the paper.

Folds on Documents. When paper is folded a ridge is produced on one side along the line of the fold and a corresponding depression on the other side, the character and permanency of the ridge and depression depending upon a number of factors, the principal of which are the nature of the paper ; the pressure exerted to produce the fold and the pressure to which it is subsequently subjected ; the length of time the paper has remained folded and the number of times it has been folded and unfolded at the same place. If the paper is brittle from any cause, such as poor quality, age, or heavy loading, the surface breaks at the fold and, should this be across any writing, the continuity of the writing necessarily is interrupted. If a folded paper is much handled or subjected to rubbing, as for instance by being carried in the pocket for a considerable time, the outside edges of the folds are abraded and any writing on them is effaced partly and if the abrasion is sufficient to wear holes in the paper, naturally any writing present at these places on either side of the paper will disappear. In the case of the partial or total disappearance of writing due to the breaking or abrasion of the paper at a fold the cause usually is manifest plainly and, as a rule, no difficulty is experienced in establishing the sequence of the writing and folding.

When writing is made across an existing fold it is practically impossible

[1] See also P. Chavigny, " Identification of Scissors by Traces left on Paper " *Journal of Criminal Law and Criminology*, 36 (1936), pp. 920–924.

to do this in the uniform, natural manner of writing made on a flat surface, whether the writing is across the ridge on one side or across the depression on the other side, but more especially when across the ridge. The ink strokes generally show variations from the normal in width and sometimes in slant, and there may be also abnormal pen lifts and even tiny gaps in the continuity of some of the strokes. If the surface of the paper has been broken at the fold before the writing was made the ink " runs " in an unmistakable manner and even on fairly good quality paper there is frequently sufficient disturbance of the surface fibres at the fold to cause some slight " running " of the ink.

Documents with Torn or Serrated Edges. Reference has already been made to the necessity of examining the edges of a document which purports to have been cut or torn accidentally and which has been mounted on other paper, since sometimes the edges at the joins do not correspond. Correspondence or non-correspondence between the edges of paper may also be of considerable evidential value in the case of documents having one or more serrated edge, such as postal and fiscal stamps; cheques; certain receipt forms, which have been attached to counterfoils by means of perforations and sheets from block-notes, where the top edge is perforated o facilitate detachment.

Mitchell [1] quotes a case where one perforated edge of each of two stamps used for separate receipts made out to the same person, but dated three months apart, corresponded exactly, which supported other evidence that the receipts were fictitious. Symons [2] gives an instance where stamps originally forming one block of three had been used separately on three promissory notes purporting to have been made at intervals of about a year.

In a trial in my experience it was claimed by the defence and denied by the prosecution that a loose sheet of paper having a serrated top edge, on which was written what purported to be part of the minutes of a meeting, had been torn from a particular place in a certain block-note. This block-note originally had 49 sheets, of which 35 remained, 14 sheets, not all in consecutive order, having been removed, the narrow counterfoils at the top, however, remaining. The sheets were all ruled, both horizontally and vertically, with faint blue lines.

In the case of nine counterfoils out of the fourteen the loose sheet could not possibly have been attached, since among other points of dissimilarity the ruled vertical lines at the extreme left-hand side of the loose sheet did not correspond in relative position with the analogous line on any of the counterfoils. In four other instances the perforations on the loose sheet

[1] C. A. Mitchell, *Documents and their Scientific Examination*, pp. 177–9.
[2] C. T. Symons, *Report of the Government Analyst for the Year* 1930, *Ceylon* (*Analyst*, **56** (1931), p. 668.)

did not correspond with those on any of the counterfoils and hence again the loose sheet could not have been attached. There only remained, therefore, one counterfoil to which the loose sheet could possibly have belonged, if it belonged to that block-note at all, and it was to this that the defence alleged it to have been attached, this particular counterfoil being the next but one [1] preceding a sheet still attached to the block-note on which was written what was sworn in evidence to be a continuation of the minutes on the loose sheet. This one counterfoil was so firmly pressed against the preceding and succeeding counterfoils, owing to the tight manner in which the block-note had been bound, that it was found impossible to separate the perforated edge sufficiently for a satisfactory examination or for a photograph, for which purposes it would have been necessary to have taken the block-note apart and to have flattened out the edges of the perforations on the questioned counterfoil, many of which were turned up, but this was not allowed. So far as could be seen, however, there were many agreements between the perforations on the counterfoil and those on the loose sheet and no essential differences, but the dispute remained unsettled with a probability that the loose sheet did belong to the counterfoil in question. The matter was one of considerable importance as it was connected closely with an alibi in a murder case.

During the war of 1914-1918 two blank sheets of paper that had been sent by post in different envelopes to the same person were submitted, and it was found on examination that the sheets each had one torn edge that fitted together. In a second similar case two other blank sheets of paper, each again having one torn edge that corresponded, had been sent by post to two different persons in the same hotel and the addresses on both envelopes were in the same writing. Since no evidence of secret writing could be found in either instance it seemed probable that the sheets of paper were some sort of code message.

In all cases of torn or serrated edges that are thought to match, an enlarged photograph will be found helpful not only during the examination, but also for production in Court.

Stains and Marks on Documents. See pp. 138-139.

Photography of Documents. See pp. 250-252.

Ink. The principal kinds of ink employed at the present day are carbon ink, iron-gall ink, logwood ink and aniline ink.

Carbon Ink. Carbon is the oldest ink material known : it was employed by the ancient Egyptians and other nations of antiquity and is still used largely in Egypt and the East at the present day. The date of the earliest use of carbon ink cannot be stated, but in Egypt two inscriptions (one on

[1] A reasonable explanation was given to account for a sheet having been missed.

a bowl and the other on a jar sealing) of the First Dynasty (more than 3000 B.C.) are recorded by Petrie,[1] and inscriptions on nine red pottery vases of the same dynasty were found by Emery,[2] all being almost certainly in carbon ink. The Prisse papyrus of Eleventh Dynasty date (2160 B.C. to 2000 B.C.) and the Papyrus Ebers (about 1500 B.C.) are also almost certainly written with carbon ink. A number of specimens of ancient Egyptian black ink examined by me were proved to have been made from carbon.[3] These included three from writing palettes of the Eighteenth Dynasty (1580 B.C. to 1350 B.C.), a number on various ostraca (undated) and a number on papyri varying in date from Roman times to the ninth century A.D.

Carbon ink was made anciently probably from soot scraped from cooking vessels. A recipe for making ink from incense, for use in writing religious books, was supplied kindly to me by a priest of the Coptic Church. This is as follows: Put a quantity of incense on the ground and round it place three stones or bricks and, resting on these, an earthenware dish, bottom upwards, covered with a damp cloth; ignite the incense. The carbon formed is deposited inside the dish, from which it is removed and made into ink by mixing with gum arabic and water. An old Arabic book in the Royal Library, Cairo (unfortunately anonymous and undated) contains a recipe for making what is called Persian ink. The method is to take date stones, put them in an earthenware vessel stoppered with clay and put the vessel over a fire until the next day, then remove, allow to cool, grind and sift the contents and make into ink with gum arabic and water. Such an ink would be of a very different composition from that previously referred to and might contain very little free carbon.

When wood or similar organic matter is charred by heat it is generally assumed that the resulting blackening is due to the formation of free carbon and, under certain conditions of temperature, undoubtedly this is the case, but various black organic compounds, such as tarry matter, are also formed, and it seems possible that at relatively low temperatures free carbon may be almost absent. As the result of experiments made on the solubility of charred wood in a solution of bleaching powder and in nitric acid respectively, Boodle [4] arrived at a similar conclusion.

Having occasion to consult, in the Egyptian Government archives, Cairo, some old Arabic documents dating between 1026 A.H. (A.D. 1617) and 1288 A.H. (A.D. 1871), I noticed that although generally speaking the ink was black, yet in some cases it was brown or partly brown. Other instances

[1] W. M. Flinders Petrie, (*a*) *The Royal Tombs of the First Dynasty*, **1**, pp. 15, 21; (*b*) *The Royal Tombs of the Earliest Dynasties*, **2**, p. 38.

[2] W. B. Emery, *The Tomb of Hemaka*, 1938, pp. 51–52.

[3] A. Lucas, "The Inks of Ancient and Modern Egypt," *The Analyst*, **47** (1922), pp. 9–14.

[4] L. A. Boodle, "The Nature of Charred Wood," *Bull. of Misc. Information, Royal Botanic Gardens, Kew*, 1917.

of the same phenomenon noted are (*a*) the ink on papyrus manuscripts dated between A.D. 622 and A.D. 719 exhibited in the Royal Library, Cairo; (*b*) the ink on manuscript Qorans dated between A.D. 719 and A.D. 912 exhibited in the same library; (*c*) the ink on papyrus documents dating from the time of the Roman occupation of Egypt to the ninth century A.D.; (*d*) the ink on a series of eight title deeds for land varying in date from 1246 A.H. to 1287 A.H. (A.D. 1830 to A.D. 1870) and (*e*) the ink on the account books and two of the religious books already referred to.[1] It was not possible to examine the ink chemically in every instance, but that on *c*, *d* and *e* was tested and found to be a carbon ink and not an iron ink. It must therefore be accepted that what was originally a black ink of the carbon type sometimes does become brown. This at first sight seems extraordinary and even impossible, since the characteristics of carbon are its black colour and unalterability, carbon ink always being regarded as the type of a permanent ink. It is of course not contended that ink in which such change has taken place was ever a good quality carbon ink, for manifestly this was not the case, but the ink in question is not an iron ink and originally was a black or practically black ink, accepted and used as an ink of the carbon type. An ink made according to the second of the methods mentioned might well be of this nature. In any case it must be assumed that when the document was finished the writing was uniformly of a dark and practically black colour, and hence the disappearance of this colour must be accounted for and it is suggested that the ink contained little or no free carbon in the first instance, but contained black compounds, possibly of a tarry nature, that have turned brown and also in some cases a small proportion of iron compounds, that have also become brown and that the brown colour has masked any small amount of carbon present. In some instances the carbon of the ink possibly may have rubbed off the paper leaving a brown stain due to a small proportion of some ingredient other than carbon that was present. Irvine states [2] that carbon black made from natural gas contains bodies of a dirty brown colour that show as a kind of halo surrounding the letters when the black is used to make printing ink. Some such bodies possibly may be present also in carbon produced by other methods than from natural gas. In the case of the manuscripts exhibited in the Royal Library, Cairo, referred to there is in several instances a definite brown-coloured zone round the black letters and where writing shows through the paper from one side to the other it is often brown. It has been noticed too that where writing has become copied accidentally on to a page opposite, probably owing to the paper having deen damp at some time, the copy

[1] See pp. 71–72.

[2] R. Irvine, "On the Preparation of Carbon Black from Natural Gas in America," *Journ. Soc. Chem. Ind.*, **13** (1894), p. 131.

may be brown although the original writing is black. In this connexion it may be mentioned that Lehner states [1] that "most European-made Indian inks are distinctly brown when diluted to any great extent." The change of colour of black ink to brown is mentioned by Berthelot.[2]

In the case of two manuscripts on leather, dated 233 and 239 A.H. respectively (A.D. 848 and 853), the ink originally has been black and is still black in places, but in other places it is white and manifestly some change has taken place, but of what nature it is impossible to say without a chemical examination; the white, however, does not appear to be a fungus growth on the surface of the ink as at first was suspected.

When carbon ink is used on a good quality well sized paper, such as the parchment-like paper frequently employed in Egypt for title deeds of land, the ink does not penetrate the paper and can be washed off. A common illustration of this is that when testing carbon ink frequently it is noticed, after applying the usual tiny drop of reagent and using blotting paper to absorb the excess, that the ink on the small portion of the writing tested has disappeared partly or wholly from the paper and if the test solution employed happens to be one that bleaches, the explanation at once suggests itself that the colour has been bleached and therefore is not carbon, though what has happened is that the ink has become loosened from the paper by the solution and has been removed mechanically by the blotting paper, to which it can be found adhering. Care therefore is necessary to distinguish this washing off from bleaching. That ink probably made from carbon could be removed from documents with water was known to Pliny.[3]

Iron-gall Ink. At what period iron-gall ink was employed first is not known, but the earliest literary reference to it that can be traced is in the eleventh century A.D.,[4] though undoubtedly it was used several centuries earlier. Wiesner, in his account of certain Arabic papyri from Egypt, states that the writing on these, which date from the third to the seventh century A.H. (ninth to thirteenth century A.D.), is made with two different kinds of ink, one a carbon ink and the other an iron ink.[5] The ink on a number of fragments of parchment documents, dating from the seventh century A.D. to the twelfth century A.D., examined by me, was an iron compound in every case. Schubart mentions [6] a brown ink found on papyrus dating from about the fourth century A.D., which from its colour

[1] S. Lehner, *Ink Manufacture*, 1914, p. 119.

[2] M. Berthelot, *Archaeologie et Histoire des Sciences*, 1906, pp. 143–4.

[3] *Natural History*, 24, 1.

[4] C. A. Mitchell, *Inks: their Composition and Manufacture*, 1937, p. 8.

[5] J. Wiesner, *Mittheilungen aus der Sammlung der Papyrus Erzherzog Rainer*, Wien, 1887, pp. 11–111; 239–40.

[6] W. Schubart, *Einführung in die Papyruskunde*, Berlin, 1918, p. 44.

might be an iron ink, since a brown colour generally indicates an ancient iron ink, though this is not always the case, carbon ink sometimes becoming brown, as explained already. Writing that was brown has been noticed on vellum manuscripts of both the fifth and sixth centuries A.D.

Milne and Skeat writing of the Codex Sinaiticus (fourth century A.D.), which is on vellum, say " the ink was in the main an iron compound." [1]

It should not be forgotten that certain carbon inks contain slight amounts of iron compounds and therefore they give the reactions for iron, in consequence of which it has been suggested that carbon ink was sometimes deliberately mixed with iron ink. This, however, is most improbable and has never been proved, any iron present being much more likely an impurity in the carbon.

As originally made, iron-gall ink consisted essentially of a mixture of ferrous sulphate and an infusion of nut galls. This when fresh gives only a faint colour on paper but gradually oxidises and darkens and finally becomes black. In order therefore that there should be an immediate coloration when the ink was used it was customary to oxidise it during manufacture. Later it was found preferable that oxidation should take place after the ink had penetrated into the fibres of the paper and so oxidation during manufacture was dispensed with and, in order to obtain an immediate coloration, a provisional blue colouring matter, sometimes indigo but more generally an aniline colour, was added, and this mixture constitutes the modern blue-black ink, the manufacture of which dates from the early part of the nineteenth century, although both logwood and indigo had been used to a small extent in order to strengthen the colour during the previous century. When a blue-black ink is used, at first only the blue colour shows, but after a time this becomes masked by the formation of the black compound resulting from oxidation. Such an ink also oxidises and becomes black gradually if left exposed in an ink pot. This colour change provides a valuable means of determining within certain limits the age of an ink. Thus ink that is very blue to the naked eye is very recent, if violet it is less recent, and if black still less recent. But an ink that is black to the naked eye may still be violet or even blue when seen through a lens or microscope, and it is only after a considerable time that the ink becomes completely black.[2] Mitchell states that a thin wash of an iron-tannate ink when exposed to strong light becomes oxidized almost completely in about a week, but that if the ink is applied in the ordinary way with a pen and afterwards kept in a closed book the final intensity of colour may not be

[1] H. J. M. Milne and T. C. Skeat, *Scribes and Correctors of the Codex Sinaiticus*, 1938, p. 79.

[2] In order to compare and register the exact tint of an ink, the comparison microscope, designed by Osborn is recommended. (A. S. Osborn, *Questioned Documents*, 1929, pp. 67, 69, 91, 92.)

reached for upwards of a year.[1] Osborn[2] states that for an American blue-black iron-gall ink under American conditions to appear black to the naked eye a period of a few weeks is required in the summer, and from one to several months in the winter, while for the ink to be of a real neutral black, even when examined microscopically, a period varying from about two to four years is required, and that the colour is then fixed for a number of years, after which it begins to turn yellow at the edges, finally becoming a yellowish brown.

In some tests made by me it was found that in the month of January in Cairo, Stephens' blue-black writing ink lost its blue colour to the naked eye in two days, one locally-made blue-black writing ink lost its blue colour in one day, while in the case of a second locally-made blue-black ink for fountain pens, after the blue colour disappeared a violet tint formed which persisted up to and including the twelfth day from the time the writing was made. With the microscope and a magnification of forty diameters and upwards all three inks showed a slight dark violet colour three years after the writing was made. With a lower magnification than forty diameters the inks looked black.

The tendency of the modern ink manufacturer is to put into his ink an increasing proportion of aniline blue, in order that it may be more distinct and more pleasing in colour when first used, and accompanying this there is also a decreasing proportion of the real ink ingredients, with the result that the blue colour is so pronounced and the iron compound is so reduced that the masking of the preliminary blue colour by the developed black colour is much slower than was formerly the case.

In this connexion the writing in a number of registers was examined. It was found that some of the writing fourteen and a half years old when seen with the naked eye was grey, some black and a small amount brown. Of the writing in the subsequent years part was grey and part black, but none brown; the writing from six months to eighteen months old was chiefly black. In no instance was there any blue or violet tint. No writing less than six months old was examined. The ink used was a blue-black iron-gall ink, but possibly not of the same make in every case. A number of dated documents were also examined. These varied in age from one month to seven years. To the naked eye none of the ink showed any blue or violet tint, but with one exception all were grey or black, the exception being brownish-black and the document four and a half years old. Under the microscope most of the documents, up to and including those three years old, showed a definite blue or violet tint, the colour being

[1] C. A. Mitchell, "Estimation of the Age of Ink in Writing," *The Analyst*, 45 (1920), pp. 249–50.

[2] A. S. Osborn, *Questioned Documents*, 1929, p. 469.

more marked the more recent the writing. There were, however, two exceptions, one being four months old and the other two and a half years old, and in both instances the colour of the ink varied from grey to black. Beyond three years no blue or violet tint was distinguishable, the ink being brown in one case (four and a half years old) and grey or black in all other instances. In these cases therefore no blue or violet was visible to the naked eye after one month (no observations of ink less than one month old were made), but blue or violet was visible with the microscope up to three years, with only two exceptions, one being four months and the other two and a half years old respectively.

Another indication of the age of iron-gall ink when in the form of writing is that when recent it reacts rapidly with certain reagents, but that after a time this reaction proceeds more slowly and finally the ink remains comparatively unaffected. For this test Mitchell [1] recommends a 5 per cent. solution of oxalic acid, a drop being applied to the writing by means of a capillary pipette and the result observed with a lens. In order for a correct comparative estimation of the age of two inks to be made it is necessary that the dates of the inks should not be too close together, that the inks should be of the same type and that the differences found should be very pronounced. The fact that ink has been blotted may modify considerably any conclusions to be drawn from either the colour or the time of reaction.

The result of the chloride test for determining the age of ink on a document as described by Türkel [2] is very difficult of interpretation, since so many factors are concerned.[3] [4] One factor not usually taken into account, but one that should not be neglected, is the possible presence of chloride, not from the ink, but from the paper itself or from finger prints on the paper, perspiration always containing chloride. The sulphate " pictures " [5] are still more uncertain. It has been shown, too, that the presence or absence of blue dye in an ink is no proof of age.[6]

There is no general rule for determining the age of an ink from the colour, since much depends upon the nature of the ink and whether or not it was fresh when the writing was made, or whether it had been exposed already for some time in the ink pot, also upon the degree of exposure to which

[1] C. A. Mitchell, (*a*) " Estimation of the Age of Ink in Writing," *The Analyst*, **45** (1920), p. 253 ; (*b*) *Inks : their Composition and Manufacture*, 1937, pp. 209–211.

[2] (*a*) Mezger, Raal and Heese, *Arch. Kriminologie*, **92** (1933), p. 107 ; (*b*) C. A. Mitchell, *Inks : their Composition and Manufacture*, 1937, pp. 213–215.

[3] R. E. Cornish, J. Finn, Junr., and W. McLaughlin, " Age of Ink as Determined by the Chloride Test," *Industrial and Engineering Chemistry, News Edition*, **12**, No. 17 (1934), pp. 315–6.

[4] J. Finn and R. S. Cornish, " Determination of Age of Inks by the Chloride Method, *Industrial and Engineering Chemistry*, **30** (1938), pp. 524–525.

[5] W. Hess, *Archiv. für Kriminologie*, 1935, **96**, pp. 13–17 ; *Analyst*, **60** (1935), p. 338.

[6] C. E. Waters, " Blue Dye as Evidence of the Age of Writing," *Industrial and Engineering Chemistry*, **25** (1933), pp. 1034–5.

the writing has been subjected, the temperature and humidity to which it has been exposed and the nature of the paper and whether or not the writing has been blotted.[1]

It may be mentioned that in a prominent advertisement of a well known blue-black ink a curious mistake has been made. This advertisement is one showing a large blot of ink with the name of the manufacturer or the word " Ink " written across it. The blot is coloured black in the centre and blue at the edges, which is the reverse of what happens, an ink blot being entirely blue at first and darkening gradually at the edges where the film of ink is thinnest and becoming black in the centre last of all.

Neither carbon ink nor aniline ink can be dated even approximately from chemical evidence, since neither undergoes that progressive chemical change with lapse of time that is so characteristic of a blue-black iron-gall ink.

Logwood Ink. The use of a decoction of logwood as an ingredient in ink was known as early as 1763 and at first the logwood was employed as an addition to iron-gall ink, but in 1847 logwood was used with potassium chromate and in 1859 with alum, in both cases without any iron compound.[2]

Aniline Ink. The first aniline dye was mauve, discovered by Perkin in 1856 [3]; in 1859 fuchsine was made and aniline blue in 1861 [3]; in 1863 Hofmann discovered the violet that bears his name [3]; eosin was made in 1874,[4] and malachite green in 1878.[5] The first British patent for the use of aniline dyes in ink was dated 1861, followed by others in 1862.[6] Nigrosine was introduced for stylographic pens in 1867.[6] Coloured inks, however, were known before the introduction of aniline dyes; thus a mineral red (red ochre) was used by the ancient Egyptians and red and green inks (also mineral products) were used by the Romans.

Coloured aniline inks, chiefly violet, are used largely in the East, even for important documents such as wills, promissory notes, deeds of sale and receipts. Ink of this kind fades on exposure and the nature and extent of the exposure condition the appearance of the ink much more than mere age. It may be mentioned, however, that aniline colours in the form of ink of the kind used for duplicating purposes with such an apparatus as the hectograph for example, are frequently resistant even to strong sunlight, on account of the thickening ingredients present, whereas copies of documents made with such ink fade readily.

[1] See H. T. F. Rhodes, " The Oxidation of Ferrous Iron in Iron Gall Ink," *Chemistry and Industry*, 59 (1940), pp. 143–145. Also H. T. F. Rhodes, *Forensic Chemistry*, pp. 108–111.
[2] C. A. Mitchell, *Inks: their Composition and Manufacture*, 1937, pp. 139–141, 142.
[3] W. H. Perkin, *Journ. Soc. Arts*, 1868.
[4] Benedekt and Knecht, *The Chemistry of the Coal Tar Colours*, 1889.
[5] W. H. Perkin, *Journ. Soc. Chem. Ind.*, 4 (1885), p. 426.
[6] C. A. Mitchell, *Inks: their Composition and Manufacture*, 1937, p. 147.

Sometimes a signature written with violet ink is suspected because it is lighter coloured than the ink on the body of the document or than that of other signatures, but little can be done in such cases and the lighter colour may be due to the ink having been blotted. In one case submitted to me the authenticity of a document written in violet ink was questioned because the ink was darker in colour than that on another document bearing the same date ; the evidence, however, was in favour of it being genuine.

In another case in which the validity of a document relating to the sale of land was contested, the whole of the document, including the signatures, was written with violet ink and therefore no chemical examination of this could give any indication of its age. The prosecution contended that the signature of the most important witness had been added at a later date than the other signatures, while the defence produced photographs (both negative and prints) showing this signature and the absence of a certain dated registration stamp which seemed to prove that the signature had been on the document at a date prior to that assigned to it by the prosecution. The fact that the grain of the paper of the document and considerable gradations of light and shade existed on the photographs, as also two numbers that showed through the paper from the opposite side, was proof that the registration stamp had not been blocked out or otherwise removed from the negative for the purpose of obtaining a photograph without it and that the photograph had been taken before the document was registered. The registration stamp, too, crossed a fold where a corner of the paper had been turned down to allow an endorsement on the other side to show on the photograph and the sequence of the fold and some writing on the registration stamp corroborated the other evidence that the photograph was taken before the document had been registered.

When dealing with photographs it should not be forgotten that both negatives and prints are easily " faked." Thus a negative may not be the original negative, but a secondary one to which something not on the original has been added or from which something has been removed, or the print may have been made from a " faked " original or from a secondary negative. It is a commonplace of photography to block out undesirable features in a negative and to make additions, such as a suitable background to a portrait or clouds in a landscape.

In a further case examined a document bore various genuine consular registration stamps and was endorsed on the back with violet ink that showed through the paper. As seen from the face, however, the colour of the endorsement was not violet but green and, since it is a well known chemical fact that certain acids turn aniline violet a green colour, acid was tested for and was found to be present to an extent impossible in a paper that had not been subjected specially to acid treatment and on further examina-

tion it was discovered that part of the original writing had been effaced and a forged name and other details substituted. The fact that gum had been used in this and in several other instances to reglaze the paper after the original writing had been removed was additional proof that the documents had been tampered with, since gum is never used for such a purpose by the paper manufacturer.

Testing of Ink. Sometimes it is necessary to determine the nature of the ink on a document, since this may serve as an indication of age or as a proof of alterations or additions. The testing is carried out by applying minute drops of various reagents to the writing by means of capillary pipettes or small, thin, pointed pieces of wood, such as wooden toothpicks, and examining the result with a lens, and this can be done so carefully that any marks left are so small that it is difficult afterwards to find them. When writing has been tested chemically a note should be made of the places to which the reagents have been applied and these should be indicated in the report.

Ward carries out the testing as follows[1]: "A small pipette, with a capillary end less in external diameter than the breadth of the stroke under examination, is slightly charged by placing the tip in contact with the surface of the reagent, and a minute drop is placed upon the ink-stroke by pressing the pipette tip gently into contact with it. The drop is immediately covered with a small watch glass to prevent evaporation, and allowed to remain one or two minutes: meanwhile the pipette is completely emptied, and is then applied to the drop, which is thus withdrawn from the ink-stroke. The drop is then gently expelled on to a glass slip and allowed to evaporate, the dry (unless glycerol is present) residue being examined under the microscope and photographed." Ward recommends a one per cent. solution of acetic acid as being the most generally useful reagent and this he employs also for aniline-dye inks, copying-ink pencils and rubber-stamp impressions.

It cannot be insisted upon too strongly that suspected documents should be treated with the greatest care and that no one without considerable experience in delicate manipulation should be allowed to test them. Sometimes an alteration to a document consists of a few letters or figures only, or even of part of a single letter or figure, and unless the greatest precautions are taken, the disputed portion of the writing will be so defaced as to become useless as evidence. In cases of this nature it is inadvisable to test the ink.

In view of the comparatively large number of reagents for testing ink on documents often recommended, perhaps it is as well to state that very

[1] T. J. Ward, "The Microchemical Identification of Ink in Handwriting," *Analyst*, 59 (1934), pp. 621–2.

few are required, the most useful being dilute hydrochloric acid (strength not more than 5 per cent.), dilute sodium hydroxide (strength about 2 per cent.) and a solution of bleaching powder, or better, of sodium hypochlorite (10 per cent.). Oxalic acid, tartaric acid and acetic acid are occasionally useful substitutes for hydrochloric acid and may be employed in greater strength than the mineral acid without fear of injuring the paper. Sulphuric acid, although frequently recommended, should never be used, since inevitably it will damage the document seriously. This damage may not take place at once, but only gradually, and hence may not be apparent until some time afterwards. When testing fresh or comparatively fresh ink, potassium ferrocyanide, which is employed frequently as a test for iron in ink, is less valuable than sodium hydroxide, since it labours under several disadvantages, one being that it decomposes readily, giving the reaction (a blue colour) it is used to test for, and another that it reacts with any iron compounds in the paper as well as with those in the ink. Also, since potassium ferrocyanide solution is acidified with hydrochloric acid before use, this latter renders visible the blue colour due to any provisional colouring matter in the ink, which may mask any other blue due to iron compounds. When testing old inks both potassium ferrocyanide and potassium thiocyanate are necessary and are then to be preferred to sodium hydroxide. When using these reagents a minute drop of hydrochloric acid is placed first on the ink in order to dissolve the iron, and this is followed by a drop of ferrocyanide or thiocyanate. One disadvantage of sodium hydroxide is the manner it spreads on the paper, but the effect of this may be minimized by using the smallest possible quantity and by removing the excess with blotting paper as soon as the result of the test has been noted. Another disadvantage is that it produces a brown colour on paper of poor quality that may disfigure the document. No matter what reagent is used, it is a wise precaution to remove the excess remaining after the reaction has terminated, by means of blotting paper, or better to wash it off by applying successive drops of water that are absorbed afterwards by blotting paper.

Carbon ink is distinguished from most other writing inks by the fact that it remains unaltered when treated with a solution of bleaching powder or of sodium hypochlorite. Other reagents are also without effect.

The fact already mentioned that carbon ink can readily be removed from documents provides a good test for this ink. A drop of water is placed on a small piece of filter paper, which is applied to the writing and pressed down with the thumb-nail. If the ink is a carbon ink, a little will come off generally and will be found as a black stain on the filter paper and can be tested. Occasionally an iron ink, especially an old iron ink, will transfer in the same manner, but the presence or absence of iron can be ascertained

readily by applying a drop of hydrochloric acid, followed by a drop of potassium ferrocyanide or of potassium thiocyanate.

Both iron ink and logwood ink, unlike carbon ink, give very marked positive reactions with various reagents. The principal results are shown in the following table :

Reagent.	Iron-gall Ink without Blue Colouring Matter.	Iron-gall Ink with Blue Colouring Matter.	Logwood Ink.
Hydrochloric acid . .	slightly yellow	blue	red
Oxalic acid . . .	bleaches	blue	red
Tartaric acid . . .	bleaches	blue	light brown
Acetic acid . . .	bleaches	blue	violet
Sodium hydroxide . .	reddish-brown	reddish-brown	brown
Potassium ferrocyanide (*a*) .	blue	blue	—
Potassium thiocyanate (*a*) .	red	red	—
Sodium hypochlorite . .	bleaches	bleaches	bleaches

(*a*) After the iron has been dissolved by a drop of hydrochloric acid.

In several cases investigated alterations to documents written with carbon ink had been made with an iron ink containing a provisional blue colouring matter and in one instance a document written with carbon ink had been altered twice, in one place with an iron ink and in a second place with logwood ink. In another case a document written with iron ink had been altered with carbon ink.

Many of the results of the chemical examination of ink on documents, that are to be found in the literature of the subject, have reference to an iron-gall ink without provisional blue colouring matter and therefore are misleading, since practically all ordinary writing inks now contain a blue colour.

It is suggested sometimes that in order to test the nature of aniline ink on a document, or even of any kind of ink, a press copy of the writing should be taken so that this may be tested chemically instead of the original. This should never be done. In the case of aniline ink it is sometimes allowable to take a copy of a few unimportant letters or words, if such exist, but in no circumstances should a press copy be made of a suspected alteration or suspected signature or date. As already mentioned, if the testing is done carefully there need not be any disfigurement of the document. With respect to violet ink only one substance is generally employed, namely methyl violet, and therefore chemical tests as a rule yield no useful results.

For blue inks different compounds are used and some of these may be distinguished from one another even when in the form of writing.[1] When dealing with blue ink the following caution should be noted, namely, that an ordinary iron-gall ink containing a blue colouring matter, if very recent,

[1] C. A. Mitchell, *Inks : their Composition and Manufacture*, 1937, p. 166.

is blue and when tested with hydrochloric acid, oxalic acid, tartaric acid or acetic acid it remains blue or may become still more blue, owing to the removal of colour due to the iron compound and the consequent rendering visible of the blue already present. Such an ink, too, gives a reddish-brown colour when tested with sodium hydroxide. When blue aniline inks, that are sometimes used for writing, are tested with these same reagents, they also remain blue with acids and in some cases give a reddish-purple colour with sodium hydroxide and, unless care is taken, such an ink might be mistaken for a very recent blue-black iron ink.

For red inks there are several satisfactory tests. The dye used principally for making red ink is eosine, but other dyes such as cotton scarlet, ponceau scarlet and fuchsine also are employed and the following method of distinguishing between them when on a document may be mentioned :— With bromine water eosine becomes yellow, but the red colour is restored by the addition of sodium hydroxide ; cotton scarlet also becomes yellow with bromine water, but on the addition of sodium hydroxide a brown colour is formed ; sodium hydroxide applied directly to cotton scarlet produces a puce colour that disappears after a time ; with bromine water ponceau scarlet at first becomes yellow and then bleaches and fuchsine turns a violet colour, that becomes yellow or orange on the addition of sodium hydroxide.[1]

Occasionally it is found that a few words or figures in red ink on a document are suspected because of their dark colour, but this may be due to a black-ink pen having been used by mistake at the beginning of the writing or to the pen having been dipped subsequently and inadvertently into black ink.

In one book dealing with questioned documents, the chemical testing of ink is described as " quite simple," and it is stated that " the cost of the necessary material and the time required to make onself proficient as a capable tester are so slight that even the small fee that would be charged by a chemist is scarcely worth paying." It is certainly true that the cost of the reagents required is slight, chiefly because the quantity used is so minute, and the method of testing like everything else is simple when one knows how to do it, but the manner proposed for determining the presence of acid in an ink on a document by placing " the tip of the tongue to a thick stroke " cannot be recommended, nor is it advisable to put so much water on a document that some of it can be poured subsequently into a test tube, as is advocated in the book in question. A " point of a pin " as suggested as a means of applying acid is also unsatisfactory. The only right way of testing ink on a document is that already mentioned, namely, to apply an exceedingly small drop of the requisite reagent by means of a fine capillary

[1] See also C. A. Mitchell, *op. cit.*, p. 167.

pipette or a small, pointed piece of wood, and to examine the result with a lens.

The spectroscopic method of testing ink on a document described in a recent publication [1] cannot be recommended, since in the process some part of the writing must be cut out and destroyed and the document thus disfigured, and apparently the only useful result is a delicate test for chromium, should a chromium compound happen to be present in the ink, a very rare occurrence. Any destruction or disfigurement of any part, however small, of a disputed writing should be avoided.

Sometimes blue-black writing inks may be differentiated by means of photography,[2] Mitchell recommending an ordinary " process " plate.[3]

Mitchell has shown [4] that blue-black writing inks, not only known to be different, but manifestly different to the eye, cannot be distinguished from one another by means of ultra-violet rays, also that writing of different ages made with the same ink cannot be distinguished. Any examination of blue-black ink, therefore, by ultra-violet rays is of little or no use. Ultra-violet rays, however, often may serve to distinguish similarly coloured writing or typing inks from one another.[5]

Ward has shown [6] that the sediment in writing ink, if examined microscopically, may yield facts of value in identifying ink derived from a particular ink pot or in identifying the common source of the ink used for different documents. A case in point that occurred in my experience is mentioned later.[7]

Pens. In England and most other countries the only pen now used is a metal pen, the quill pen formerly employed having become practically obsolete, though in the East pens analogous to the quill are still employed ; thus in Egypt a reed pen is very common, though it is being superseded gradually by a special form of steel pen. This reed pen in its present form dates from Roman times, before which date a thin rush, from one-sixteenth to one-eighth of an inch in diameter, was employed and the end, instead of being cut like the present reed pen in the same manner as a quill, was cut chisel-shaped, the narrow edge being used for fine lines and the wide edge for thick lines.

[1] S. Smith and J. Glaister, *Recent Advances in Forensic Medicine*, 1939, p. 217.
[2] C. A. Mitchell, *Inks : their Composition and Manufacture*, 1937, p. 219.
[3] C. A. Mitchell, " Scientific Documentary Evidence in Criminal Trials," *Analyst*, 57 (1932), p. 146.
[4] C. A. Mitchell, " Ink and Ultra-Violet Light," *Analyst*, 55 (1930), pp. 746–7.
[5] C. A. Mitchell, " The Use of Invisible Rays in Criminology," *The Medico-Legal and Criminological Review*, 3 (1935), p. 8.
[6] T. J. Ward, " The Photomicrography of Ink Sediment in Pen Writing," *Analyst*, 55 (1930), p. 568. Also C. A. Mitchell, *Inks : their Composition and Manufacture* 1937, pp. 223–225.
[7] See p. 123.

The first steel pen on record was made in England in 1780 and others were made and sold in 1803. The first patent for the manufacture of metallic pens is dated 1808. Machine-made pens were introduced in 1822.[1]

The writing made with different kinds of pens often can be distinguished by the general appearance, the shading and the width of the ink lines. Even writing made with different pens of the same kind may be distinguished if the points are of different fineness. It is a useful precaution in connexion with the examination of forged or anonymous documents to ascertain whenever possible the kind of pen used by the suspected writer. Two instances in which steel pens have been used with fraudulent intent for writing, alleged to be of a date before their invention, are given by Mitchell.[2]

Pencil Writing. Pencils used for writing may be either blacklead or they may be coloured, the colour generally being violet, such pencils being termed " indelible " or " copying " or " copying-ink " pencils, but blue and red pencils also are used.

Blacklead Pencils. Blacklead (graphite) pencils were not known before the discovery of graphite in Cumberland about 1560, earlier pencils being made either of metallic lead or of a lead alloy.

Sometimes it is stated that it is impossible to distinguish between one blacklead pencil and another when in the form of writing, but Mitchell [3] has shown that under certain conditions writing done with different pencils may be differentiated both by microscopical examination and by chemical tests.

For the microscopical examination a low magnification (1-inch objective) and a strong side light are employed. The variations in the marks made by different pencils consist of (*a*) differences in the colour and distribution of the pigment, (*b*) the presence and nature of certain striations and (*c*) a brilliant lighting effect sometimes observed on the paper. Mitchell states that too much importance should not be placed upon differences in the depth of colour observed, since under variations of pressure marks from hard pencils may resemble and may be mistaken for those made by soft pencils.

The chemical tests applied to blacklead pencil writing consist principally of tests for iron and chloride, but may include a test for sulphate and also a test with dilute nitric acid. For iron a drop of 80 per cent. acetic acid or of strong nitric acid is placed on the writing, followed by a drop of potassium ferrocyanide, different pencil marks showing pronounced

[1] Article " Pen " in *Encyclopædia Britannica*, 11th ed., 1911.

[2] C. A. Mitchell, *The Scientific Detective and the Expert Witness*, 1931, pp. 146–8.

[3] C. A. Mitchell, (*a*) " Blacklead Pencils and their Pigments in Writing," *Journ. Soc. Chem. Ind.*, 38 (1919), pp. 383–90 T ; (*b*) " Graphites and other Pencil Pigments," *Analyst*, 47 (1922), pp. 379–87 ; (*c*) *Documents and their Scientific Examination*, 1922, pp. 87–117.

differences in the colour produced. The presence or absence of chloride also serves to distinguish between the writing done with different pencils. For this reaction a drop of dilute nitric acid is applied to the writing and silver nitrate solution is then added to the drop, which should retain its globular form throughout the test. A test for sulphate with nitric acid and barium chloride or barium nitrate occasionally may show differences, or sometimes there is a difference in the behaviour with dilute nitric acid alone.

Writing made with a blacklead pencil that apparently has been erased completely with an indiarubber may become partly visible again with lapse of time. A notable example of this was the Whalley will case,[1] the explanation being that although writing immediately after erasure may not be visible it may not have been removed completely, but a portion may remain covered up by loose fibres of the paper that have been disturbed by the indiarubber, or on the inner surface of fibres that have curled up, and after a time the former partly regain their normal position and the latter uncurl, thus in both cases revealing the writing.

Pencil marks that have been partly effaced sometimes may be deciphered if photographed, for which purpose the light should fall upon the writing from one side and at an angle, or they may be developed at the back of the paper by brushing it over with a coloured solution or a coloured powder or by means of iodine vapour.

In one case of a partly effaced document written with blacklead pencil on poor quality paper found on the body of a drowned person I found it impossible to develop or intensify the writing, and although ten different photographs were taken under various conditions of illumination and exposure, none of them was helpful, the writing being deciphered best with the naked eye when the paper was held obliquely.

Mitchell [2] has drawn attention to the fact that examination by ultra-violet rays sometimes may be useful for detecting erased blacklead pencil writing, the tiny particles of graphite left more or less buried in the paper fibres reflecting the rays and becoming visible, though if only lightly made the writing may be removed so completely that no detectable indications are left. Even in such cases, however, if the paper has been rendered more transparent by the erasure this area will appear as a black patch.[3] In two cases in my experience the results have been negative.

A collection of photographs and photomicrographs of pencil markings has been published.[4]

Copying Ink Pencils. The most complete investigation of this subject

[1] C. A. Mitchell, *Science and the Criminal*, 1911, p. 147.
[2] C. A. Mitchell, " Inks and Ultra-Violet Light," *Analyst*, 55 (1930), p. 746.
[3] C. A. Mitchell, " Erasures and Ultra-Violet Light," *Analyst*, 58 (1933), pp. 532–3.
[4] S. Türkel, " Atlas der Bleistiftschript," *Analyst*, 1930, pp. 603–604.

that can be traced is by Mitchell.[1] The tests applied are both microscopical and chemical. When examined with the microscope definite differences in colour sometimes may be seen with writing made with different pencils. Different pencil marks also show characteristic differences when tested with different solvents. Water, alcohol, ether and acetic acid should be tried in turn, a drop of the solvent being placed on the writing and the result observed with a lens. It should be noted whether there is any solution of colour and whether this solution is immediate or not, and finally the drop should be soaked up with a small piece of filter paper. The residue on the document, particularly that left after acetic acid, should be examined microscopically when graphite if present will be seen and a difference in the amount may be found in the case of different pencils.

To test the colour chemically the spot obtained by placing a drop of alcohol or acetic acid on the writing and then absorbing it by means of filter paper is allowed to dry spontaneously and various reagents, such as nitric acid, hydrochloric acid, stannous chloride, sodium nitrite with acetic acid and sodium hypochlorite with acetic acid are then applied, the colour effects produced being observed with a lens. The residue left on the document after the removal of the colour with acetic acid should be tested for iron with a 5 per cent. solution of potassium ferrocyanide. Another useful test is that for chloride and for this a drop of silver nitrate is applied directly to the writing.

In a murder case Mitchell gave evidence that writing in copying-ink pencil on some fragments of partially burnt paper from the grate of the room where the body was found gave identical results when tested with that of a copying-ink pencil belonging to the accused person, who admitted that the writing had been done by him.[2] The accused, however, was acquitted on other grounds. The writing made with different kinds of copying-ink pencils sometimes may be distinguished by means of infra-red photography.[3]

Mitchell has shown that writing done with copying-ink pencils is affected very little when immersed in sea water for long periods.[2]

Blue and Red Pencils. The most important work on the subject that can be traced is by Mitchell.[4]

In the case of blue pencils, the pigments employed include aniline colour,

[1] C. A. Mitchell, (*a*) " Copying Ink Pencils and the Examination of their Pigments in Writing," *Analyst*, **42** (1917), pp. 3–11 ; (*b*) *Documents and their Scientific Examination*, 1922, pp. 118–37.

[2] C. A. Mitchell, (*a*) " Copying Ink Pencils and the Examination of their Pigments in Writing," *Analyst*, **42** (1917), pp. 3–11 ; (*b*) *Documents and their Scientific Examination*, 1922, pp. 118–37.

[3] C. A. Mitchell, " The Use of Invisible Rays in Criminology," *The Medico-Legal and Criminological Review*, **3** (1935), p. 13.

[4] C. A. Mitchell, " Graphites and Other Pencil Pigments," *Analyst*, **47** (1922) pp. 384–6.

Prussian blue, ultramarine blue and cobalt blue, all of which even in the form of writing may be distinguished by treatment either with hydrochloric acid or with potassium hydroxide solution.

The pigment used for red pencils is often red lead, but may be an aniline colour. The writing made with different red pencils, even if all are red lead, sometimes may be distinguished by the reactions given on treatment with hydrochloric acid.

To compare differences in shade of colour the Comparison Microscope designed by Osborn [1] will be found useful.

Alterations and Erasures. Generally these can be seen with the naked eye, but if skilfully done a microscopic examination is required to detect them, a binocular stereoscopic microscope being recommended. Enlarged photographs, too, are very helpful. Special hints on the taking of such photographs will be given in the chapter on Photography.

Occasionally documents are submitted to the expert in which it is stated that alterations have been made, but which on examination are found to be perfectly genuine. Alterations may be alleged because the ink has " run " in places, and fraudulent additions may be suspected because some of the writing is unnecessarily close together. It may, however, be possible to prove not only that no alteration or erasure has been made, but that any " running " of the ink is due entirely to the poor quality of the paper, and if any part of the writing touches or crosses another part, the determination of the sequence of the strokes will settle the question of whether additions have been made or not.

Sometimes a suspected erasure turns out to be a smear, or a suspicious appearance may be due to the use of thick ink or a bad pen. Sometimes too, although an alteration has been made it is in an unimportant detail and is due manifestly to the correction at the time of writing of a slight inadvertent error and is of no consequence. Instances occur also in which a serious but unconscious mistake has been made at the time of writing, for example in a figure such as a date, an amount representing a payment or a price, and it is claimed afterwards that the figure has been tampered with, but in such cases generally it can be shown that no alteration has been made. Mistakes and alterations, too, even in their own signatures, are not uncommon in the writing of uneducated persons, especially those of advanced age, and various instances of this have been investigated.

The testing of documents for erasure by means of iodine vapour or by heating, both of which sometimes are recommended, is not as a rule either advisable or necessary. If iodine vapour is used, the colour partly disappears on standing and may be discharged completely by means of sodium

[1] A. S. Osborn, *Questioned Documents*, 1929, pp. 77, 471–3.

thiosulphate. Heating is never satisfactory and may injure the document seriously.

If chemical erasure is suspected the paper should be tested for hypochlorite with iodide of starch paper and for acid with blue litmus paper, care being taken when using the latter that the litmus paper is not too wet, otherwise it may discolour the document.

The testing for manganese by means of the spectroscope, in order to prove the use of potassium permanganate as an ink eradicator, described in a recent book,[1] is not recommended, since for the test some portion (although only a small one) of the disputed section of the document must be cut out and destroyed and the document thus disfigured.

One of the most valuable methods of examining documents for possible erasures is by means of ultra-violet rays, under which any disturbance of the surface fibres of the paper and any partly erased writing are shown clearly. If any erasure becomes visible it should be photographed. Photography by means of infra-red sensitive plates occasionally may give useful results.

Sequence of Strokes. A very common kind of fraud in documents is the addition of further writing after a document is completed. In such cases there is frequently very little spare space and the added writing often touches or crosses some part of the original, and when this occurs the sequence of the strokes frequently may be determined by microscopical examination, using preferably a binocular stereoscopic microscope, and the facts observed may be demonstrated in Court by means of enlarged photographs. Great care, however, is necessary before a definite opinion is given as to the sequence of crossed strokes, particularly if either of the strokes has been blotted, since if one stroke is thick and the other thin, the thick stroke will appear always uppermost whether it is actually so or not. A stamp impression made with a rubber stamp and coloured ink over a strong black ink writing always appears underneath. Under certain conditions the second of two strokes crossing one another widens out where it touches the first stroke and the ink spreads upon the first in a manner that is definite and characteristic, and when this occurs it furnishes proof of the true sequence.[2] [3]

Illegible Writing. This refers to writing that has faded or has been partly effaced, and not to that illegible on account of the manner in which it is written. The possibility of restoring faded writing depends upon the

[1] S. Smith and J. Glaister, *Recent Advances in Forensic Medicine*, 1939, p. 218.

[2] C. A. Mitchell and T. J. Ward, " The Sequence of Strokes in Writing," *Analyst*, **52** (1927), pp. 580–4. Also C. A. Mitchell, *Inks : their Composition and Manufacture*, 1937, pp. 217–218.

[3] A. S. Osborn, " Sequence of Strokes in Blotted Writing," *Analyst*, **53** (1928), p. 35.

composition of the ink and the conditions that produced the fading, inks containing iron offering the best prospects of restoration, while aniline inks as a rule cannot be restored. The former may be restored in a number of ways, including exposure to sulphuretted hydrogen or to the vapour of ammonium sulphide or by brushing over with a dilute solution of tannic acid or of ammonium sulphide, or by careful treatment with a dilute solution of potassium ferrocyanide followed by ammonia, which give a brown colour, the shade depending upon the amount of iron present. With ferrocyanide alone a blue colour is produced. Sulphuretted hydrogen and the vapour of ammonium sulphide, despite the disagreeable smell of these reagents, are to be preferred to tannic acid or liquid ammonium sulphide, since they do not discolour the document and, although the results are fugitive, they may be repeated as often as necessary and even may be re-produced in Court. In two instances, a number of entries in soldiers' pay-books, which had been effaced, probably by means of a bleaching solution, were restored clearly after exposure to the vapour of ammonium sulphide. The vapour of sulphocyanic acid, formed by the action of dilute (10 per cent.) hydrochloric acid on potassium sulphocyanate, may also be used.[1] The use of an infusion of galls for a similar purpose was described as early as 1660.

Illegible writing frequently shows up well when exposed to ultra-violet rays [2] or in certain cases when photographed with infra-red sensitive plates [3] and these methods therefore constitute tests that should never be neglected and both have proved valuable in the examination of ancient documents and of palimpsests.

Sometimes it may become necessary to decipher writing or printing that has been obliterated deliberately by covering it with a coating of ink or colour, as was done for instance by censors during the war. As a rule copying-ink pencil, blue pencil, blue ink, blue-black ink and printer's ink can be removed by treatment with suitable solvents to a sufficient extent to enable the matter underneath to be read. Often, too, it is possible to obtain a legible photograph of obliterated writing by using strong light and coloured filters, but the best results may be obtained by photographing by means of infra-red sensitive plates.

On one occasion in connexion with a crime, a letter was found so soaked in blood as to be illegible, and I tried to remove the blood so that the writing could be read. This, however, proved impossible, since the ink

[1] (*a*) E. O'Neill, *Journal of Criminal Law and Criminology*, **27** (1936), pp. 574–577 ; (*b*) R. Turner, *Journal of Criminal Law and Criminology*, **32** (1941), pp. 257–8.

[2] Government Chemist, *Report upon the Work of the Government Laboratory for the Year ending 31st March*, 1927, p. 32.

[3] Anon., " Infra-Red Photographs of Illegible Leather Manuscripts," *The British Museum Quarterly*, 8 (1933), pp. 52–3.

used was aniline blue that was soluble in water and in all the other solvents in which the blood was soluble. In the Podmore murder case a scrap of paper was found bearing writing in copying-ink pencil, much of which was illegible owing to the paper having been trodden upon and stained with oil and dirt. This was cleaned with benzene (benzol) and the writing, which was rendered visible, played an important part in the arrest and conviction of the murderer.[1] [2]

The task of deciphering writing that has been effaced partly is much more difficult when the language is a foreign one, since with a language that is familiar a certain amount of reasoned guesswork may be employed by means of which a working hypothesis is obtained, that can be verified or discarded later.

Secret Writing. The most important kind of secret writing is that by means of ciphers and codes, after which in importance comes the use of invisible or sympathetic ink. The former will not be dealt with, as it is outside my experience, and also because it is not a chemical matter. The latter will be treated briefly, since there are many things in connexion with the subject that it is inadvisable to publish, especially developments made during the recent war.

Any colourless or almost colourless solution that can be used with pen and paper may be employed as an invisible ink, even plain water.

Description of a few invisible inks may be found in various books, as also the methods of developing them, but the possibilities are almost endless, and a large number of such inks could be devised for which it would be practically impossible, without being informed of the nature of the ink, to find the correct developer. This does not mean, however, that development would be impossible, but merely that chemical development might be impossible. To realize the distinction it will be necessary to consider what an invisible ink is and in what development consists.

Invisible inks, with a few exceptions, that will be referred to later, consist of water containing some chemical ingredient in solution, and such inks are invisible merely because they are colourless or practically colourless. Chemical development consists in so changing the nature of the ink that it becomes coloured and therefore visible. This change may be brought about by light, by heat or by appropriate chemical reagents.

But the act of writing, whether the ink is invisible or not, does more than merely place the writing fluid on the paper. In the process the surface of the paper, the special physical condition of which is produced by pressure and heat, generally becomes scratched by the writing instrument, and also

[1] C. A. Mitchell, *The Scientific Detective and the Expert Witness*, pp. 166–7.
[2] The Southampton Garage Murder Case (The Podmore Case). *The Police Journal*, 4 (1931), pp. 325–36, 484–99.

is partly destroyed, or at least affected to some extent, by the solution used, and even writing made with distilled water and a soft brush affects the paper and can be developed. In some cases too the writing fluid may act upon the sizing or the loading material of the paper. The result of the alteration of the surface is to make the paper more absorbent, and hence if a coloured solution is applied, the colour is retained mechanically to a greater extent in those parts where the writing occurs than on the rest of the paper, and the writing therefore becomes visible. Also coloured powders adhere more firmly to those places where the surface of the paper has been affected by the writing. The application of coloured solutions or coloured powders therefore constitutes a valuable means of developing invisible inks.

The value of secret writing is not that it cannot be developed unless the nature of the ink is known and the correct chemical developer applied, for most invisible inks can be developed by physical methods, but its value consists in the fact that secret writing may escape detection unless suspicion is aroused and special search made.

When secret writing is suspected both physical and chemical development should be tried, beginning with the former.

Before applying any method of development the suspected document should be examined carefully in the ordinary way by reflected light, also by transmitted light and more especially by ultra-violet rays, under the influence of which latter most invisible writing fluids show up clearly. This method is not only rapid and simple and leaves no trace to indicate that an examination has been made, but the results may be photographed and thus made permanently visible. When making the examination by reflected light, this should be allowed to fall both directly on the paper, for which purpose a strong light is required, and also obliquely, for which the light should not be too strong.

When glazed paper is used the presence of secret writing frequently can be detected by careful inspection, whatever the nature of the ink may be, and even with unglazed paper the writing sometimes may be seen. On paper with a rough surface secret writing cannot as a rule be detected by inspection except under ultra-violet rays.

An examination for invisible ink by means of a lens or microscope is not of much value and is seldom necessary.

The methods of development referred to will now be described.

LIGHT. Exposure to light develops certain silver salts.

HEAT. This develops writing made with fluids such as cobalt salts, copper salts, lemon juice and other fruit and vegetable juices,[1] milk, solutions

[1] Formalin added to a fruit juice renders the writing less readily developed by heat. See C. A. Mitchell, *Documents and their Scientific Examination*, pp. 156, 165.

of sugar, dilute sulphuric acid and urine. The most satisfactory manner to apply this test is by means of a carefully regulated electric oven, but a hot iron also gives good results, an electrically heated one being the best. Documents on which there are wax seal impressions should never be heated in an oven, but always ironed, the wax being avoided : documents made of celluloid, which is sometimes used for Christmas, New Year and birthday cards, should not be heated, since this material, unless specially prepared is very inflammable.

OXIDATION. Dyes, such as fuchsine, that have been decolorized, may be developed by exposure to the air, the process being one of oxidation.

REDUCTION. It is stated [1] that certain invisible inks containing metallic compounds may be developed by immersion in a bath of silver nitrate (1 per cent.) and a reducing agent whereby a thin coating of silver is deposited on the writing, which is thus rendered visible. The reduction of course occurs in the developer and not in the ink.

ULTRA-VIOLET RAYS.—This method had been mentioned already. Exposure to ultra-violet rays renders visible a large proportion of solutions employed for secret writing, including acetic acid, ferrous sulphate, hydrochloric acid, lime juice, milk, oxalic acid, potassium ferricyanide, potassium ferrocyanide, potassium thiocyanate, quinine bisulphate and urine, but not saliva.

INFRA-RED RAYS. Photography by infra-red rays sometimes may be helpful in developimg secret writing.

COLOURED POWDERS. The powder either should be sprinkled or sprayed on the document or applied by means of a soft brush, the latter method being the best, any excess being blown or brushed off. Almost any coloured powder, even dust or ashes, will do if it is in a sufficiently fine state of division, but graphite, iron oxide (such as jeweller's rouge) and red lead are the best. Coloured powders develop most invisible inks, including lemon juice, milk, saliva, salt, sugar, urine, water and most chemical reagents.

COLOURED SOLUTIONS.[2] The use of such a solution appears to have been suggested first by Forgeot in 1891 for the purpose of developing invisible finger prints on paper and he employed ordinary writing ink.[3] The modification of this test suggested by Nicefero,[4] also for developing finger prints on paper, is very satisfactory, not only for that purpose, but also for developing secret writing. It consists in diluting ordinary blue-black writing ink with water, applying this to the paper by means of a brush and then washing off the excess. Almost any coloured water solution,

[1] J. Boyer, " German Spies and Invisible Writing," *Conquest*, 2 (1921), p. 57.
[2] Except iodine solution, which will be dealt with separately.
[3] R. Forgeot, *Des empreintes digitales, étudiée au point de vue médico-judiciaire*, 1891.
[4] A. Nicefero, *La Police et l'Enquête Judiciaire*, 1907, p. 174.

however, will do, thus red ink may be used or a solution of any aniline colour. Although the finger print or the secret writing is developed without the subsequent washing of the paper, the latter is essential if the best results are to be obtained. A solution of a water soluble blue, such as methylene blue, also will be found satisfactory. This is painted on the paper by means of a brush, the paper afterwards being put under a tap and rinsed well with running water. When dealing with a large sheet of paper, or with one that requires treatment on both sides, generally it will be found advantageous to put the paper boldily in the solution instead of using a brush, the procedure followed being identical with that employed for developing photographs, the dish containing the developer being rocked from side to side. This method develops a large proportion of invisible inks and is one of the most satisfactory for general use. In many cases the action is merely one of selective absorption, but in some instances, especially when physiological fluids have been used for writing, the dye in the developing fluid is mordanted on to the paper by some constituent in the ink. Mitchell has shown that with saliva developed with iron-gall ink the action is partly chemical.[1] A solution of an aniline dye in alcohol will answer the same purpose as a water solution.[2] In this case the paper is allowed to remain several minutes in a dilute alcohol solution of the dye and then is rinsed with alcohol. This alternative method might prove useful in case there was any writing on the paper, other than the invisible ink, that was soluble in water but not in alcohol, and which it was desired to retain.

Dilute solutions of oil in alcohol or other solvent are employed sometimes as invisible inks, and hence form an exception to the rule that invisible inks are water solutions. The oil used is generally castor oil, which is one of the very few fixed oils soluble in alcohol, but essential oils also may be employed. These latter, however, are unsatisfactory, since they disappear in time by evaporation. Such inks may be developed by soaking the paper in water, when the writing becomes translucent and visible. Occasionally, however, the secret writing is of the nature of an artificial watermark which is made while the paper is wet by placing over it a dry sheet and writing on this with a hard and blunt-pointed pencil or similar instrument, which leaves an impression on the damp paper underneath, writing made in this way being invisible when the paper is dry, but can be seen plainly if examined by transmitted light when the paper is wet, and hence may be developed by soaking the paper in water. One example of this came under my notice during the war. A solution of bismuth nitrate in dilute nitric acid, that is recommended sometimes for use as invisible ink, also can be developed

[1] C. A. Mitchell, *Documents and their Scientific Examination*, p. 158.

[2] An alcoholic solution of an aniline colour is used sometimes to develop finger prints on glass. R. A. Reiss, *Manuel de Police Scientifique*, p. 422.

by water. Dilute acetic acid, hydrochloric acid, nitric acid and oxalic acid may be used for secret writing and can be developed in the same manner, the writing becoming translucent and visible when wet.

CHEMICAL REAGENTS. The chemical compounds that might be used as developers are innumerable and it is only possible to try a few general reagents of different classes, the following named being the best:

Ammonia. For substances, such as phenolphthalein, that form coloured compounds with an alkali and for salts, such as those of copper, that form coloured hydrates.

Ammonium Sulphide. For the salts of metals that form coloured sulphides, such as cobalt, copper, iron, lead, nickel and tin.

Ferric Chloride. For tannic acid, potassium ferrocyanide[1] and some organic compounds, for example, antipyrine.

Ferrous Sulphate. For tannic acid and potassium ferricyanide.

Iodine. This, which is the best all-round developer for secret inks, may be employed either in dilute solution or as vapour. The action, though occasionally chemical as for instance in the case of starch,[2] is generally merely physical. When used as a solution, iodine is applied best with a brush. When used as vapour, which is more satisfactory than the solution, a few crystals of the solid substance are put at the bottom of a vessel, in which, or over which, the document to be tested is placed, and the vessel is allowed to stand until sufficient vapour has been given off to stain the paper, or is heated gently. On no account should the solid iodine be allowed to touch the document, and the exposure should be only of short duration, otherwise the whole document becomes darkly coloured and illegible. As iodine vapour is both objectionable and injurious care should be taken not to inhale it. If the document is not too large, it may be curved round the inside of a glass beaker, with the written side uppermost, and the beaker covered with a glass plate during development. A formula for a developer consisting essentially of a dilute solution of iodine in potassium iodide, but containing also sodium chloride, aluminium chloride and glycerine, has been published,[3] for which it is claimed that it "will reveal any invisible ink known to science." One disadvantage of the use of iodine is that it

[1] Potassium ferrocyanide is most unsatisfactory for secret writing since it decomposes slowly on the paper and becomes visible.

[2] Vanishing ink made from a solution of rice starch coloured with iodine may be restored by exposure to iodine vapour.

[3] H. Ashton-Wolfe, "Secret Writings and Invisible Inks," *Illustrated London News*, 25th August, 1928, p. 360. This consists of potassium iodide 4 grams: iodine 0·1 gram: sodium chloride 5 grams: aluminium chloride 2 grams: glycerine 3·5 grams: water 30cc. The aluminium chloride must be added very gradually and the solution kept cool, otherwise a violent reaction occurs. The solution is applied by means of a pad of cotton wool.

stains the paper and, although most of the staining is temporary and disappears spontaneously by the evaporation of the iodine, some little discoloration and smell frequently persist especially in any creases and at the edges of the paper, thus indicating that the document has been treated, a revelation that often it is desirable to avoid. Any iodine remaining may be decolorized by means of sulphur dioxide [1] or a dilute solution of sodium thiosulphate (the hypo of the photographer), but the latter may interfere with subsequent development and so may reveal that the document has been intercepted and read. Since iodine is such a useful and generally used developer it was to be expected that efforts would be made to find a defence against it and it is known now that it is possible so to treat a document that iodine and some of the other general developers will not reveal secret writing. As this method of treatment, which is very simple, has been published,[2 3 4] it may be mentioned: it consists in gently sponging the paper, after the secret writing has been made and allowed to dry, with a dilute solution either of ammonia or of sodium thiosulphate (hypo) or even with plain water, or by immersing the document momentarily in these solutions, after which the paper is allowed to dry and finally pressed with a cold iron. The action of the treatment is to modify the whole surface of the paper in the same manner as it is modified by the secret ink in those portions covered by the writing. This treatment also tends to prevent the writing from showing slightly before development, as it does not infrequently on glazed paper. Documents treated in the manner described can be developed as a rule with coloured solutions, but the best safeguard is to examine them by means of ultra-violet rays.

Potassium Ferrocyanide and Potassium Ferricyanide. For ferric and ferrous salts respectively.

Tannic Acid. For iron salts generally.

The above reagents in the form of dilute solutions are applied best by means of a soft brush, a stroke being made diagonally across the paper as a preliminary trial.

It should not be forgotten that all seemingly blank pieces of paper, even though sent as letters through the post, do not necessarily bear invisible writing, a blank sheet sometimes being placed round a letter to prevent the writing showing through the envelope. Sometimes, too, a sheet of blank paper is sent as a specimen or to supply writing paper to some one likely to be without,[5] or as a pre-arranged signal, or even as a practical joke. Sometimes what is suspected to be secret writing is merely an accidental

[1] Readily made in small quantity by the action of an acid upon a sulphite.
[2] J. Boyer, "German Spies and Invisible Writing," *Conquest*, 3 (1921), p. 56.
[3] S. T. Felstead, *German Spies at Bay*, 1920, p. 270.
[4] H. O. Yardley, *The American Black Chamber*, pp. 40, 46.
[5] Especially in the case of business letter paper with printed heading.

transfer of other writing, laterally inverted, with which the paper has been in contact.

Writing that has been developed and is still not very distinct often gives excellent results when photographed.

In some instances the manner in which a sheet of paper is folded, creased or marked by intended lines constitutes a code or signal: the water-mark too may be prepared specially and may convey a message or have a secret meaning.

In the case of letters sent through the post, the inside of the envelope and underneath the postage stamp should be examined specially. Even the position of the stamps on the envelope may be a signal. In one case in my experience a portion of the lettering on a postage stamp had been obliterated, leaving the figure indicating the value of the stamp to serve as part of a message.

Some of the substances used during the war of 1914-18 as invisible ink were articles of everyday use that could be bought openly and carried without suspicion, others were uncommon materials, such as organic compounds of silver that were intended to be developed with special reagents, but it was found that they could be developed also by physical methods. Some of the ways of carrying and sending supplies of ink were very ingenious and particulars respecting many of them have been published.[1] [2] In some cases the ink was made up to resemble medicine, soap, toothpaste, throat gargle, pomade, perfume, or other toilet preparations or was concealed in such articles. One method of carrying supplies was to saturate socks, shoe laces, handkerchiefs, neckties, cotton gloves, the cloth covering of buttons, scarves or soft collars with the writing solution and afterwards dry them, and when the ink was required it was recovered by soaking the article in water. The ink was generally colourless or almost colourless and so did not show, and the socks, neckties, shoe laces or other articles used were often black.

Typewritten Documents. At first thought it might appear to be impossible to distinguish between one typewritten document and another, if both are done with ink of the same colour, but frequently such discrimination is a fairly simple matter. Typewriting machines all have a distinct individuality and documents made, not only with different makes of machines but with different machines of the same make, generally can be recognized and even the approximate age of a typewritten document sometimes can be determined. It is well known, for instance, that different makes of machines have type of a slightly different shape and size, and hence the make of machine can be ascertained from an examination of the shape

[1] H. O. Yardley, *The American Black Chamber*, pp. 34–40.
[2] Sir G. Aston, *Secret Service*, p. 308.

and a careful measurement of the size of the letters on a questioned document. All typewriting machines, too, deteriorate with age and constant use, and characters made with any machine show defects that did not exist when the machine was new and that do not exist in any other machine even of the same make, and hence a typewriter records its own individuality and its own history in a manner that cannot be disputed. A frequent occurrence is for some of the letters to get out of alignment, and this provides one of the ways in which the writing of any particular machine may be identified.

With respect to the age of a document, it is well known, for instance, that typewriters of certain kinds were not made before certain dates and also that alterations are being made constantly in practically all machines in order to improve them, and, since many of these changes affect the size or style of the letters, all such alterations therefore constitute definite evidence of age. Thus the capital letters of the Smith Premier machine were narrowed in 1896, and when a few years later a document dated 1893 was produced in connexion with an important case that was being tried in Court, which bore the narrow capitals only introduced in 1896, it was manifest that the document was a forgery, and it was traced to a particular machine and its history discovered.[1]

In one case the characteristics of a particular machine to which the suspect had access were so evident and so numerous that a certain forged document could only have been typed on that machine. Thus in a comparatively short document the " a " was below the line twenty-four times ; there was abnormally wide spacing after the " i " eighteen times ; the " O " was above the line four times ; the " o " was above the line twenty-three times and the " p " was not vertical, being inclined to the right nine times, and all these features occurred not only on the questioned document, but also on the comparison copy of it typed with the machine in question.

In a second case there were seven possible machines on which an anonymous document might have been typed and it was a comparatively simple matter to eliminate six of these and to prove that the seventh had been used.

In a third case any of forty-seven different machines might have been used to type an anonymous document, but the possibilities were soon narrowed down to an Imperial machine having a particular size of type and a particular form of " 3 " and " 4," which excluded twenty-four machines, leaving twenty-three others for further consideration. Of these, twenty-one were excluded by reason of the nature of certain faulty alignment. The mal-alignment of the remaining two was very considerable, much alike in the two machines, which were of the same make, and agreed generally with that of the anonymous document, but eventually, by having a number

[1] A. S. Osborn, *Questioned Documents*, 1929, p. 585.

of copies of the document typed by different typists from both machines, only one possible one was left.

In a fourth case the machine on which two forged certificates had been typed was identified from five others, not only by the abnormally wide spacing between certain letters, but more particularly by the fact that the letter " y " was defective.

It may be mentioned as a matter of interest that Arabic typewriters were introduced into Egypt about 1903, the first machine put on the market being " The Idris and Haddad," which was employed in the Government offices almost from the date of its appearance. In 1911 the " Monarch " Arabic typewriter, now called the " Smith-Premier," was introduced, and about the same time the " Yost " Arabic machine appeared, and in 1921 a new Arabic typewriter called the " L'Ahram " was brought out. These dates, therefore, constitute time limits for Arabic typewritten documents in Egypt.

The examination of typewritten documents consists principally of a careful scrutiny and measurement of the type, more particularly with respect to the general form, small peculiarities of form and small defects, but especially the shape of the letters and the alignment. The measurement of the size of the letters may be carried out either by means of a microscope fitted with a micrometer eyepiece, or with test plates as used by Osborn.[1] Newcomb states that it is possible even to differentiate between writing done by different new machines of the same make with good alignment and with none of the letters distorted. He shows also that the spacing between the letters may vary according to the position of the letter in the typescript and the speed of the typing.[2] The spacing between words may be characteristic of a particular make of machine.

Printed Documents. The principal printed documents the expert will be called upon to examine will be banknotes, cheques and postage stamps, with possibly also share certificates and lottery tickets, but occasionally the identification of the type used for a circular or pamphlet or the comparison of one printed type with another may be required. The examination of such printed documents as those last mentioned consists principally in a careful scrutiny of the type, together with measurements of the size of the letters, but the composition of the paper and the nature of the sizing also should be determined.

Banknotes. Banknotes are protected against forgery by various devices, among which are (*a*) special paper, (*b*) water-marks freely displayed, (*c*) special designs and (*d*) special colouring. Since, however, what once has

[1] *Ibid.*, pp. 592*a*–592*g*.

[2] C. Newcomb, *Report of the Chemical Examiner for the Year* 1932, Madras (*Analyst*, 59 (1934), p. 39).

been accomplished by human agency can be repeated, it follows that all banknotes can be forged and the most that can be done to combat forgery is to make it as difficult and as expensive as possible.

The expert to whom forged notes are submitted should make himself acquainted with the methods used for the production of genuine notes and should know and be able to recognize the differences between the various methods employed.

Genuine banknotes generally are printed from engraved (intaglio) plates, with the result that the ink lies on the paper in varying depths corresponding to the depths of the engraved lines, while forged notes, although they may be, and sometimes are, printed from intaglio plates, more often are printed from half-tone blocks, zinc or aluminium plates or lithographic stones, all of which yield prints on which the ink is merely a thin, uniform film on the surface.

The forged Egyptian notes examined by me have included notes printed from engraved plates and from etched plates prepared by the bichromated colloid (albumin or gelatin) method; photographic prints in which the sensitized surfaces had been stripped from the photographs of both sides of a genuine note, fastened back to back and coloured by hand; photographic prints toned brown, which was the prevailing colour of the genuine note and notes made entirely by hand in the form of combined tracing and drawing and afterwards hand-coloured. Most of the forgeries have been so poor both in design and colouring that it is a wonder they could have deceived anyone, but some few have been well executed.

One of the best ways of examining suspected banknotes is to compare them with a genuine note while exposed to ultra-violet rays, when differences in paper, pigments and water-mark show up very clearly. This method is so rapid and effective that a large number of banks now have an ultra-violet ray equipment.

One case submitted as forgery was merely a clever confidence trick in which a rough negative copy of a banknote played a part. Finished notes were not made, nor was there any attempt to make them, the victim, however, being persuaded that forgeries, that would be undetectable, could be executed in a simple and inexpensive manner if he would supply the necessary notes for reproduction, the intention of those who worked the scheme being to secure the genuine notes and then to disappear. Similar cases have occurred in England.

Various forged notes examined were entirely hand-drawn and from internal evidence it was manifest that they were the work of at least two different persons. In one type of notes the outlines of the main features had been traced from a genuine note by means of " carbon " duplicating paper and the design then worked over by hand, the details filled in and the

note coloured. At a distance the general appearance of the face of these notes was fairly good, since the colour approximated closely to that of the original, but the colouring on the back was crude. Some of these notes were of a value of fifty piastres each (approximately ten shillings), but others were for five pounds. The evidence indicated that the forger of the notes was unacquainted with English, but was familiar with Arabic and was able to write it fairly well, though not perfectly, and therefore either that he was not an Egyptian or that he was not well educated. This man was arrested and proved to be an uneducated Egyptian whose usual occupation was that of tinsmith. Other hand-drawn notes which were put into circulation during the war of 1914-18 were probably the work of a British soldier, the English being correct and the Arabic nonsense, and were signed " D. Spoof." Forgeries of banknotes executed by hand are not unknown elsewhere and in 1913 pen and ink copies of Scotch notes for £1 and £5 respectively were made in a convict prison and various similar cases have been reported in the English daily press, one being the forgery of English ten-shilling Treasury notes and another the forgery of ten-shilling and one-pound Treasury notes, the forgeries being clever pieces of penmanship in both instances.

In one series of forged banknotes of high value a number of bogus endorsements occurred, doubtless done to convey the impression that the notes had passed through many hands. An examination of the handwriting of these endorsements helped to convict a certain person of having been concerned in the passing of the forgeries.

On one occasion a few unsigned specimen notes of a new issue of Egyptian notes were found in circulation, the word " specimen " having been effaced and a forged signature added in indelible pencil.

In several cases notes having very little design or colour have been presented at the bank for payment with the explanation that they had been sent to the laundry by accident in the pocket of some clothes. This explanation has been corroborated by chemical examination, traces of soap and alkali having been found to be present.

It is a very general practice for secret marks to be placed on banknotes. These consist usually of a slight intentional defect in the engraving, or of a slight alteration in the form of a particular letter or figure or other part of the design, or in the addition of some small special mark. Such indications are helpful in enabling a genuine note to be recognized easily and quickly and their absence is a certain proof that a note is counterfeit, no matter how good an imitation it may be. Secret marks, however, are reproduced necessarily by all photographic processes and hence their value is limited and their presence is not a proof that a note is genuine. Such marks probably never act as a deterrent against forgery.

Cheques. In connexion with printed documents cheques may be considered, although strictly they are written documents on printed forms. Cheques are protected against alteration by various devices, the principal of which are (*a*) security paper, (*b*) a sensitive coloured surface for the whole of the cheque or for the face only, or more generally for that portion of the face on which the amount and signature are written, and (*c*) perforations, all of which may be considered.

The paper is rendered " secure " by the incorporation into it at the time of manufacture of certain ingredients that cause discoloration on the application of acids or other chemicals that might be employed to remove any part of the writing.

An additional security that is present sometimes, possibly often unintentionally, is the use of a comparatively poor quality lightly-sized paper. With such a paper the ink of the writing sinks well in and may even " run " a little and any alteration is almost impossible without considerable evidence being left. A paper of too poor a quality, however, on which the ink " runs " very much, might have the opposite effect and might obscure an alteration.

A sensitive surface is produced by the use of a dye for colouring either the whole surface of the cheque or those portions on which the date, amount, name and signature are written, the colour frequently being applied in the form of a design of straight or undulating lines or of lettering in small characters, generally the name of the issuing bank printed repeatedly. Sometimes too there is a design on the back of the cheque. The colours employed for printing are sensitive to the action of acids, to many other chemicals, to aqueous solutions of various sorts and even to water alone, with the result that any attempt to tamper with the writing causes a bleaching or discoloration. This, which is the usual method of safeguarding cheques against alteration, is not an absolute protection, and an artist in forgery, of which, fortunately, very few exist, can take out such a minimum amount of colour and afterwards can so cleverly restore the missing portion that detection of the alteration is not an easy matter, except when an examination is made under the ultra-violet rays. Minute lettering is more difficult to restore than lines. Osborn states [1] that a printed background to a cheque may assist and mask a clever forgery and certainly this is the case when a design is printed in non-sensitive ink on the back of a cheque.

Cheques are protected by means of perforations in several ways, generally either by having the amount, in addition to being written in the usual manner, also punched out in the form of figures, or by having the amount in the form of words made by a series of small perforations that at the same time are inked with an " indelible " ink. Neither, however, is an absolute

[1] A. S. Osborn, *Questioned Documents*, 1929, p. 536.

protection. Cheques treated in the first of the two ways mentioned may have the perforations filled up and then may be reperforated with a higher value, while cheques treated in the second way may be altered, if the ink is not really fast to the action of chemicals, and it is the inked figures and not the perforations that chiefly are regarded, though it is possible also to tamper with the perforations.

A quick and very effective way of examining cheques suspected to have been tampered with is by means of ultra-violet rays and many banks are now provided with the necessary apparatus.

Postage Stamps. Forged postage stamps are generally reproductions of rare specimens made to sell to collectors or alterations of genuine stamps to give them an enhanced value and not forgeries of stamps in current use, except in Spain where the forgery of stamps of the current issue has been very common. During 1873, however, many thousands of forged English one-shilling stamps were sold at a particular London post office for use on telegrams and the fact was discovered only some twenty-six years later. In cases of suspected forgery a photographic enlargement both of the suspected stamps and of genuine ones of the same kind will be found helpful for comparison purposes.

The method of examination of postage stamps includes a careful scrutiny with a lens and a determination of the kind and size of the perforations, the nature of the printing ink (if possible), the kind and size of type used for lettering, including that of overprints and surcharges, the nature of the printing process employed, the nature of the water-mark and above all a careful search for minute differences in the design and a careful comparison with genuine stamps of the same kind. It should not be forgotten, however, that even in the case of genuine stamps, slight differences in design and mistakes in printing sometimes occur.

In this connexion the re-use of postage stamps from which the post office cancellation marks have been removed may be considered. The usual method of cancelling postage stamps is by means of a metal stamp and carbon-oil ink, and, if the stamp is well impressed with a good blow, the oil penetrates the paper carrying some of the carbon with it, and although the oil may be dissolved out by suitable solvents, the carbon remains and cannot be removed by any chemical means, but only by erasure, which is detected easily. In several cases investigated the removal of the cancellation marks had been done clumsily and with a lens both the signs of the erasure and the remains of the marks could be seen plainly.

The colours with which postage stamps are printed are frequently intentionally sensitive and fugitive and readily show any alteration or attempt at removal of the cancellation marks, the ink being acted upon and partly

dissolved by any solvent employed. Stamps for fiscal purposes or combined postage and fiscal use sometimes are printed with doubly sensitive ink. Sometimes, too, safety paper has been used, as for example in the English fourpenny stamps of 1855-6. Another form of protection that has been applied to paper for postage stamps and postage envelopes consisted of the insertion in the pulp of threads of cotton, linen or silk. The chalk surfaced paper now used so extensively for postage stamps also constitutes a protection against the fraudulent removal of cancellation marks.

When writing or cancellation marks have been removed from stamps in order that these may be re-used, portions of the effaced writing or marks often may be seen by means of appropriate colour screens, a red screen being used for instance when the stamp is red and the ink black.

A most valuable method of examining postal, fiscal and other adhesive stamps is by means of ultra-violet rays, when exposed to which forged stamps show marked differences if compared side by side with genuine stamps; obliterated cancellation marks become legible again; the re-gumming of genuine stamps is seen clearly; repairs show up and water-marks are rendered visible. Another valuable method of detecting obliterated cancellation marks is by photography with infra-red sensitive plates.[1]

Seal Impressions. Seal impressions in clay on various objects, particularly jars, were very common in ancient Egypt, and jar sealings from as early as the First Dynasty (before 3000 B.C.) are known. In many ancient Egyptian tombs the doorways were closed with stone and then plastered over on the outer side with gypsum plaster, on which, while it was still damp, a considerable number of large seal impressions were made with a wooden stamp, examples that may be mentioned being those in the tombs of Thothmes IV (about 1400 B.C.) and of Tut-ankhamun (about 1350 B.C.) respectively. The former is particularly noteworthy, as the seal impressions were coloured blue,[2] pigment evidently having been applied to the stamp before use. This is the earliest coloured seal impression known, though coloured wooden stamps (also generally blue) were used for sealing in other instances during the same Dynasty.[3] Red and white colours were employed in Coptic times for sealing wine jars.[3] The earliest known seal impression on a document is also from Egypt and is in red ink on a papyrus of Ptolemaic date (between 332 B.C. and 30 B.C.) found in the Fayum province of Egypt.[4]

[1] Government Chemist, *Report upon the Work of the Government Laboratory for the Year ending 31st March* 1933, p. 33.
[2] H. Carter and P. E. Newberry *The Tomb of Thoutmosis IV*, 1904, p. xxx.
[3] H. E. Winlock and W. E. Crum, *The Monastery of Epiphanius at Thebes*, 1, pp. 79, 80.
[4] A. H. Sayce, The Greek Papyri in *Hawara Biahmu and Arsinoe*, W. M. Flinders Petrie, p. 29.

Modern sealing wax of good quality consists of a mixture of shellac and resin with the necessary colouring matter and varying proportions of mineral matter; in poorer qualities the shellac is omitted. The first sealing wax of this nature of which any record can be found dates from 1554 and was made of shellac and vermilion [1]; recipes for sealing wax of various colours made from resin date from 1574.[1]

A number of mediæval English wax seals ranging in date from the thirteenth to the beginning of the sixteenth century were examined by Dobbie and Fox.[2] These consisted either of beeswax alone or of beeswax mixed with resin in various proportions, in two cases the resin being colophony, but in the other cases it could not be identified. The red seals were coloured with vermilion, the green with verdigris, the brown and black with verdigris and organic matter. The beeswax that formed the sole constituent of an impression of the Great Seal of 1350 was found to be practically unaltered either in chemical or physical properties. A thirteenth-century seal, that also consisted of beeswax alone, had been attacked by mould and had become flaky and disintegrated.[3]

In the East it is a common practice for names to be impressed on documents by means of an inked metal seal instead of the documents being signed in the Western manner. This practice is not confined to those who are illiterate, but is general, and even in Government offices the less important documents are frequently sealed. The seal is inked as a rule from a pad, a coloured aniline ink being used. Such seal impressions when made with aniline ink can be copied readily by transfer from one document to another and although transfer may be suspected, proof of this is very difficult. The reproductions generally however are relatively faint and are uniformly coloured and the outlines often blurred. The methods of transfer mentioned in several books yield very poor results and much better ones are available, though it is not advisable to describe them. The practice of using an aniline ink for the seal impression on an important document therefore is most dangerous. Aniline inks, too, are unsuitable for such a purpose on account of the ease with which they fade on exposure. Oil-carbon inks are much safer, and with a suitable ink of this nature transfers cannot be obtained when the impression is more than a few days old. The metal seals themselves also may be counterfeited, but impressions made with forged seals are detected easily when sharp, though less easily recognised when the impression is a poor one, which unfortunately frequently is the case. It should not be forgotten, however, that sometimes a seal is cleaner or is inked more uniformly, or is applied more carefully than at other times,

[1] C. A. Mitchell, *Documents and their Scientific Examination*, p. 185.

[2] J. J. Dobbie and J. J. Fox, "The Composition of Some Mediæval Wax Seals," *Journ. Chem. Soc.*, **105** (1914), pp. 795–800.

[3] For the analysis of sealing wax, see pp. 357–358.

and so impressions made with the same seal may appear different. Sometimes, too, the ink spreads on one side of a seal in such a manner as to cause the impression to appear larger than usual and of a somewhat different shape. Occasionally in cases where a seal impression is not very distinct the outlines may be traced over with pen and ink without any fraudulent intention. Sometimes, however, a seal impression is forged cleverly by inking over a tracing made from a genuine impression. Such a forgery is unmistakable when a photographic enlargement is examined.

Before it can be stated whether a given impression is a forgery or not it is necessary to compare it carefully with an impression of the genuine seal and to measure all the important lines and angles. For measuring purposes a glass plate ruled in small squares that can be placed over the impression will be found useful. Although much may be done by direct comparison, indirect methods, in which the impressions to be compared are photographically enlarged, are more satisfactory. This subject is dealt with further in the chapter on Photography.[1]

By means of a chemical and microscopical examination it is possible occasionally to ascertain whether two or more seal impressions having the same superficial appearance and colour have been made with the same ink or not, but as a rule neither the age nor relative age can be determined from chemical evidence, since the colouring matter of the ink is generally either carbon or an aniline colour.

It may be mentioned that a seal impression in black ink has been noticed on a document at the Egyptian Government archives dated 1184 A.H. (A.D. 1770), and seal impressions in green ink have been found on a number of documents dated respectively 1284, 1286, 1287 and 1288 A.H. (A.D. 1867, 1869, 1870 and 1871).

Handwriting. The examination of handwriting and the comparison of different writings is a subject that has been neglected greatly and undeservedly by scientific men, who have relegated it generally to the same category as character reading from handwriting, palmistry and phrenology and until recently it has been bound up in the bundle of the scientifically damned. This " 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 writings, 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." [2] The examination of handwriting, however, should be strictly scientific and the expert's work is, by means of scientific instruments and methods, to determine

[1] See pp. 251–252.

[2] C. A. Mitchell, *Documents and their Scientific Examination*, 1922, p. 138.

facts that his experience shows him to be present and enables him to ascertain, facts that the untrained observer would miss; to demonstrate these facts by enlarged photographs or other means and to give the conclusions that can justly be drawn from them.

The comparison of handwriting is founded upon the admitted fact of its individuality, this varying with different persons just as other features, such as appearance, physical measurements and colour, vary.

It seems at first sight a very simple matter to determine whether one specimen of writing is in the same hand as another or not, and it is quite a common experience for the ordinary man to be appealed to on such a question, and most people are quite ready to give a decision. Even the few who disparage handwriting experts because of the mistakes that sometimes have been made employ the method of comparison of handwriting in their own private affairs, and notice, and even act upon, resemblances and differences found. For example, there are few persons who do not recognize the writing of their relatives and friends upon an envelope before they open it and read the letter. The untrained person, however, bases his opinion upon the broad features of the writing only and as a rule does not pay any attention to details. Since, however, the aim of the forger is to deceive, a forgery, in order to pass muster at all, necessarily must resemble in its general aspect the writing forged, and therefore something more than the recognition of a superficial likeness or difference is required before any opinion regarding the genuineness or otherwise of a specimen of writing is of use. The study of handwriting to be of any value must be conducted according to strictly scientific methods and this can be done only by those possessing special experience, and hence in all cases of doubt or dispute regarding the authenticity of documents the matter should be referred to an expert, for not only may he discover characteristics in the handwriting that makes its origin certain, but also small points in connexion with the writing, the paper or the ink that would be passed unnoticed by an untrained observer. Thus with regard to a certain suspicious letter that was examined by me it was stated in Court that it had been commenced in a train and finished afterwards in the house, but the internal evidence did not bear this out, the writing being very regular and uniform and no part of it showed any signs of having been done in a moving train and a similar pen and ink had been employed throughout. In another case certain entries in a diary were alleged to have been written on horseback, but there was no evidence of this in the writing. A mere opinion that different documents are or are not in the same handwriting is of very little value and the expert will be asked to prove his statements, which when similarities or differences are substantial usually can be done by means of enlarged photographs.

Writing may be considered as consisting of a series of strokes and it is not necessary to know what the strokes mean or how to pronounce them in order to compare them, all that is required being a knowledge of the alphabet and of the methods in which the letters are formed and a sufficient knowledge of the language to recognize and follow the same letter or word whenever it occurs. In theory therefore the examination of one form of writing should not present any greater difficulty than the examination of any other form of writing, since whatever language a man uses, he unconsciously imparts to his writing certain characteristics that are personal and peculiar, and by means of which his individuality is expressed and may be recognized. In practice, however, I have found Arabic writing much more difficult to examine than either English or French, doubtless partly because of my imperfect acquaintance with the language, but also because Arabic writing does not show such a large number of fundamental variations as, for example, English. Although most of the handwriting cases have been in English, a large number were in other languages, namely, Albanian, Arabic, Czecho-slavak, French, German, Greek, Hungarian, Italian, Polish and several African languages, all of which with the exception of Arabic and Greek being written in Latin characters.

Method of Examination. First the known or genuine writing is examined carefully and all the important features noted. Then the anonymous or suspected document is treated similarly and the results are compared. This seems very simple and not likely to give rise to any difficulty, and yet experts differ. The cause for this unfortunate conflict of opinion is generally that the experts are not in agreement as to what constitutes "important features," one basing his conclusions on facts that undoubtedly exist but which another refuses to regard as essential. It becomes a matter of importance therefore to be able to identify the primary or fundamental features of a handwriting and to distinguish them from the secondary or non-essential features. This is where the amateur fails and where expert knowledge and experience become necessary. It is also where a biassed or unscrupulous person has an opportunity of going wrong.

It is agreed generally that no one writes the same letter, word or signature in an absolutely identical manner on different occasions, complete identity being a proof of forgery by means of some mechanical process such as tracing, transfer, printing or photography, since it is only such a process that produces results that never vary. The differences as a rule, however, are only in minor aspects, the fundamental features remaining the same. The identity between different specimens of writing, to which the expert testifies, is the practical identity produced by the same writer, which should always be explained in the report and in Court.

In the examination of a handwriting one of the first points to determine is in what particulars and to what extent it varies in itself and it is evident, therefore, that the amount of writing available is an important factor, and the larger this amount, the sounder the conclusions are likely to be. The differences that exist between different specimens of the same writing generally consist of slight variations in size, in slant, in the form of letters and the manner in which they are joined, which are due partly to the impossibility of making exact duplicates and partly to varying degrees of care taken in the writing. Some writers, however, employ two or more different forms of a letter even in the same document, for example the *t* sometimes may be crossed and sometimes not, or the *r* sometimes may be made in one way and sometimes in another, but this is soon apparent if sufficient of the writing is available and it is only another agreement and not a difference. When judging a writing the attendant circumstances must be taken into account and what are primary features in one case may be non-essentials in another. Thus it is conceivable that in a small village in England there might be one person, and one only, with a French or German education, and an anonymous letter emanating from that village, in which the figure 7 had the usual French or German cross-stroke, would be almost certainly the work of that person. In London the same feature would be much less significant, and in Cairo it would be of very little value as a proof of identity.

The principal features by means of which a given writing is identified and which together make up the general quality of the writing are (*a*) the form of the writing and particularly the interdependence and harmony of the various features, (*b*) the method employed to produce the writing, and (*c*) the punctuation, spelling and composition. Just as in personal identification it is not only by the physical features such as height, colour of hair, tone of voice, and so on, that a person is identified (each of which may be disguised) but more particularly by mannerisms of talking, walking, standing and other peculiarities of the general bearing, so in handwriting it is the unconscious tricks of style that are never disguised that are most important. Both the form and the method of formation of a writing will be appreciated better by the examiner if he copies the writing carefully several times. These factors will be considered.

Form of Writing. The form of the letters is the first point noticed when examining and comparing different handwritings, in fact, form, to which the pictorial effect of a writing is largely due, is the only feature the amateur sees and therefore he lays an undue stress upon it. A good free-hand forgery, and more particularly a traced forgery, both agree in general form with the writing forged, otherwise they would fail in their object,

which is to deceive. Also there may be a general resemblance in form between different writings due to the same style having been adopted, to family relationship or to nationality. On the other hand, different specimens of the writing of the same person may show differences of form. Form alone in its general aspect is unsafe as a guide to the identity or non-identity of two writings, since this is what the forger copies so far as he is able, but the minutiæ of form, which often the expert alone sees and of which he alone knows the significance as indicating different writing habits, are most important and constitute a basis for handwriting examination. Where the amateur goes astray is not so much in attributing too great a weight to form and in neglecting other factors, although he does both these, as in his inability, owing to lack of knowledge and experience of the subject, either to see the facts in their true perspective or to draw the right conclusions from them. One of the commonest errors is to mistake a particular style due to methods of training, family relationship or nationality for an individual characteristic and to think that two writings are by the same hand because of a general resemblance between them. Another common fault is to attribute two writings to different hands on account of differences, the amateur failing to recognize that these are confined entirely to non-essentials.

The points that merit special attention when studying form in writing are (*a*) style, (*b*) slant, (*c*) alignment, (*d*) size, (*e*) spacing, (*f*) joinings, and (*g*) peculiarities in such details as spurs, ticks, twirls, loops, buckles, the crossing of the *t*, the dotting of the *i*, and the beginnings and endings of letters.

Method of Writing. Something more than a general agreement or difference in form is required before a true opinion can be expressed regarding the authenticity or otherwise of a particular handwriting. This something is the manner in which the writing has been made, that is to say the method of formation, which although most important is generally unknown to the amateur. For example, the capital letter *I* is usually made without lifting the pen from the paper, that is to say it is written all in one stroke, but it may be made in two strokes, the downstroke being made first and the top then added. The two results may be identical in form although made in different ways. The method of formation in the example given could be detected readily by microscopical examination. Other letters and figures, *a*, *o* and 8, for example, also may be written in two entirely different ways and yet look alike. Many of the letters of a writing too often show slight differences from similar letters of other writings in the manner in which they are begun, ended and joined to the next letter.

Writing is a physical operation performed by means of the arm, wrist

and fingers with the aid of a pen or pencil. It is largely automatic and a person's conscious mentality has less to do with the result than the manner of moving the arm and hand and the way of holding the writing instrument. The characteristics shown in handwriting depend largely upon :

(*a*) The style of writing employed.

(*b*) The particular way the arm and hand rest upon the table and are moved in the act of writing.

(*c*) The manner in which the pen or pencil is grasped.

(*d*) The angle at which and the direction in which the pen or pencil is presented to the paper.

(*e*) The muscular and nervous control exercised over the writing instrument.

These, which largely determine the form of the writing, constitute the individual writing habits, and it is on a proper appreciation of these habits that much of the value of handwriting examination depends.

The manner in which the arm and hand are moved and whether it is the arm, wrist or hand that rests upon the table, and the way the pen is held, determine and limit the degree of freedom of movement of the pen and the result is a clumsy, cramped and slow writing at one extreme and an easy, flowing and rapid writing at the other, with innumerable intermediate gradations. The same factors affect the alignment and may determine also the distance between the pen-lifts which however, as pointed out by Osborn, sometimes may be merely a result of the method of writing originally learned. The way the pen is held and used and the angle at which and the direction in which it is applied to the paper determine the slant of the writing, the form of both the angles and curves and also the shading. In the study of writing habits special attention should be directed to speed, spacing, pressure, curves, angles, connexions, size and size ratios of letters and parts of letters and to the manner in which the ovals are made (whether clockwise or counter-clockwise).

Punctuation, Spelling and Composition. It is evident that peculiarities in punctuation, spelling or composition may serve as clues to the identity of the writer, and these points therefore should not be neglected. In a case of the theft of musical instruments the words " accordion " and " desert " were wrongly spelled, both in one of the questioned documents and also by the accused person.

In another case, the words " tendency," " instead," " discretion " and " everything " were spelled wrongly ; the words " storemen " and " tradesmen " were each written as two words ; the apostrophe was omitted in " don't " and wrongly inserted in " its," all of which were characteristics of the accused.

In other instances, " temporary " was written " tempory " and " please " was spelled " pleas " several times, both in the questioned writing and in the comparison documents.

Measurement of Writing. Exact measurements of a writing often provide useful indications of some of its distinctive features and are of value in demonstrating to others resemblances or differences between two writings, particularly if the measurements are plotted in a graphic form on squared paper. The actual size of letters is of no importance, as this varies constantly with the same writer, but such relations as those between the height and breadth of letters or between the heights of different letters are extremely valuable. The simplest measurements to take are the heights and breadths in millimetres of each letter in a particular word or signature. The figures obtained are generally small and it is necessary to multiply them by some convenient figure, such as five or ten, in order to have a reasonably sized graph, or still better, to measure a photographic enlargement of the writing, as in this way more accurate results may be obtained. The heights are made the ordinates and the breadths the abscissæ. A variation of this is to measure the heights only, multiply by five or ten and plot the results as ordinates, taking some convenient arbitrary figure, such as five millinetres for the abscissæ. A further variation is to measure the heights and breadths of each letter, calculate the ratio of one to the other and plot the results as ordinates with a convenient arbitrary figure for abscissæ, or the ratio of the height of each letter to the length of the word may be plotted.

Another measurement sometimes made is that of the angle of slope of the writing, but any attempt to fix hard and fast limits for this or other measurement is unwise, and a marked agreement or difference should be used merely as one of many features. In few matters is it more necessary for the expert to be on his guard against going beyond what the facts warrant than it is in handwriting comparisons.

Locard[1] uses the graphic method to show the alignment and whether the heights of the letters increase or decrease towards the end of a long word, a habit typical of certain writers. Also he represents graphically other features of a writing, such as the slant of different parts of letters and the spacing of letters, also the angles of curved letters, which is done by prolonging straight lines, axes or tangents, as the case may require, both above and below the lines, until they meet. The result is striking and often characteristic, but it has the disadvantage of not being always very precise, since frequently the parts of letters that should be straight are not straight, and curved letters and angles are so small and irregular that it becomes

[1] E. Locard, (*a*) *L'Enquête criminelle et les Méthodes scientifiques*, 1920, pp. 189–96 ;) *Manuel de Technique Policière*, 1923, pp. 156–75.

exceedingly difficult to know which part to choose for prolongation, slight variations making considerable differences in the results. Any such markings should be made on an enlarged photograph, and never on the original document. Too much stress should not be laid on the results, which represent only a few features out of many. Measurements, however, should always be made and as many ratios as possible calculated and plotted, for even if not decisive they will serve as a good preliminary sorting test. In one case in my experience nearly 800 different measurements were taken, from which ratios were calculated that proved most useful.

As examples of the use of measurements, the following cases may be quoted :

1. The number 14 written in blacklead pencil eight times on a box containing a bomb was compared with the numbers 14 and 4 in the handwriting of a suspected person. The characteristic feature was the length of the cross-stroke of the 4, and the ratio of the length of the down-stroke to the length of this cross-stroke was determined. The results were as follows :

	Ratio.
Questioned 4 (8 times)	1 to 4·1
4 in writing of suspected person (9 times) . .	1 to 3·2
4 in writing of a second suspected person (4 times) .	1 to 1·1
4 in writing of a further person (19 times) . .	1 to 1·0

The evidence, therefore, from the measurements pointed strongly to the first suspected person as the writer of the number and eventually he confessed to having written it.

2. In a case of the alleged forgery of a signature two ratios were determined, namely (*a*) that of the length of the horizontal stroke at the top of the initial letter *F* of the Christian name to the height of the vertical stroke of the same letter, and (*b*) that of the height of the letter *l* in the surname to the length of the name. The results were as follows :

		Min.	Max.	Mean
(*a*)	Genuine signatures (11 times) . .	2·2	5·3	3·2
	Questioned signatures (15 times) .	1·5	2·7	2·1
(*b*)	Genuine signatures (11 times) . .	2·9	5·4	4·2
	Questioned signatures (15 times) .	1·8	2·7	2·2

In both (*a*) and (*b*) therefore the evidence from the measurements was against the genuineness of the questioned signatures.

For measuring purposes the graduated scales engraved on glass described by Osborn are recommended.[1]

A frequent criticism made against handwriting experts is that too few documents are examined and that a certain formation stated to be a characteristic of a particular writing may occur in a large number of cases of other writing not examined. This criticism is based on a misconception of the expert's position. In order to prove the identity of the writing on

[1] A. S. Osborn, *Questioned Documents*, 1929, pp. 79–96.

two different documents, the presence in each of the documents of a number of the same features or peculiarities is established, as many as possible of these being unusual or uncommon. Reliance is not placed upon the presence of any one feature, since one or even several similar features may occur in the writings of other persons, but upon the presence of the same combination of the same features in each of the two documents, care being taken that the features are sufficient in number to exclude the possibility of chance. The absence of fundamental differences also is established. These are the same principles that are employed in personal identification and in the finger print system. The measurements of various parts of the body, the colour of the hair and eyes, deformities and scars are all personal features, but no single one is sufficient by itself to establish identity, which can be done only by a combination of features. Thus to know that a crime has been committed by a person having blue eyes is not of much help in the identification of the criminal, but " If an individual is sought who is definitely described as follows : (1) exactly five feet eleven and one-fourth inches in height, (2) blue eyes, (3) brown hair, and in addition has (4) lost his left thumb, and (5) the lower part of his right ear, and has (6) a mole on his left temple one-half inch in diameter, and (7) a tattoed anchor on the back of his left hand, and (8) a narrow scar five inches long on his right forearm, and an individual is found who exactly matches these eight points of identity, we can say without hesitation that we have undoubtedly found the man described." [1] In the Bertillon system of identification a maximum of eleven different measurements are taken, and although many hundreds of thousands of people have been examined only a very few cases are known in which two different persons have been found to possess the same combination of measurements, and in these cases other features, and notably the finger prints, were different. As a rule fewer features than eleven are sufficient to prove identity, and even one if it be marked and uncommon is significant. With regard to the finger print system, Locard states [2] that identity is proved by the agreement of twelve or more features.

Standard Writing. The standard writing used for comparison purposes should be, if possible, in the form of documents written (and signed also if possible) at a date before, but not very long before, that of the questioned document, the more genuine documents there are for examination the better the expert's knowledge will be of the characteristics of the writing. It is impossible to have too much comparison writing, but very easy, and not unusual, to have too little.

In two instances in my experience a number of possible suspects were given the questioned writing (in one instance a forged cheque and in the

[1] A. S. Osborn, *Questioned Documents*, 2nd ed., 1929, p. 225.
[2] E. Locard, *L'Enquête criminelle et les Méthodes scientifiques*, 1920, pp. 128–9.

other a forged military leave pass) and they were asked to copy it, with the result that in each instance one of the suspects, who was a good " fluent " writer, produced an excellent imitation of the forgery, which was puzzling and misleading until it was found in what manner it had been obtained.

Also, frequently the investigating officer asks the suspect to copy a word, a name, or a line of writing some six or more different times, one under the other on the same sheet of paper. More than one identical line of writing made for comparison purposes at the same time and on the same sheet of paper is of little or no more value than one, since the writer, whether innocent or guilty, unconsciously or consciously, copies the line above, or is influenced by it.

When there is little or none of the previous writing of the suspect available, he should be asked to write at least several lines in ink if the questioned document is in ink, or in pencil if the questioned document is in pencil. This writing should be from dictation if spelling is important, but generally from a typed copy, and the matter should include all the significant letters, both capital and small, and figures in the questioned document. This should be written three times, each time on a different sheet of paper, each sheet being removed before the next is written, and each sheet being signed and dated by the writer, and properly witnessed.

Anonymous Documents. In the case of anonymous documents not only should the writing be examined and compared with that of the suspected person, but the paper and ink also should be examined, since these may provide important clues. In many instances the writer of anonymous letters is never traced, but in a few cases definite proof of identity may be obtained, and even when this cannot be done occasionally it is possible to clear a person who has been suspected wrongly. In a country like Egypt evidence of nationality, that sometimes can be proved from the writing, spelling or composition, may be useful.

In one instance in which it was important to trace the origin of an anonymous document, this was done from the evidence afforded by the ink, that on the document and some found in a bottle in the house of the suspected person, when examined and compared, being characteristic and identical; it was a blue-black writing ink of poor quality and contained a large amount of finely divided insoluble matter, and probably had been made from ink powder, such as is occasionally used in Egypt and even supplied to Government offices in out-of-the-way places. In another case, well marked finger prints were found. In a third case an anonymous letter was written on a half-sheet of notepaper on which a faint reversed impression of a name and address could be deciphered which manifestly had been present as a stamped heading on the other half of the sheet.

Anonymous documents often are made by pen-printing (block lettering), the impression being very common that such lettering is not characteristic of the writer. This, however, is wrong, and although there may not be in pen-printing such a number of distinctive features as in ordinary writing, there are usually sufficient to prove the identity of the writer.[1] In one instance in my experience pen-printing was used for a number of telegrams and no difficulty was found in proving the authorship. In this case fortunately there was a fair amount of pen-printing made by the suspected person available as a standard. In several other instances, too, there have been sufficient characteristics to identify the writers.

Signatures. The examination of signatures resolves itself largely into a comparison of the suspected signature with as many others known to be genuine as possible, but includes also as a rule an examination of the nature and age of the ink. Sometimes, however, it may be inadvisable to test the ink, particularly in the case of an Arabic signature, which may consist of a few strokes only, since in some cases it can be foreseen without testing that any evidence obtained would not be conclusive, whereas it may be most important that there should not be even the slightest mark made on the writing, since this might be construed into an attempt to tamper with the signature.

When dealing with suspected signatures it should not be forgotten that although as a rule when once a particular form of signature has been adopted it varies very little and then not fundamentally, but only in superficial details, yet there are a small number of people, often not well educated and not accustomed to signing documents, who modify habitually certain features of their signature, thus for example letters like *a* or *u* may sometimes be written with one stroke of the pen and at other times with two strokes, and the manner in which letters are joined or not joined, and the absence or presence of a flourish at the end or below the signature and its form when present may be changed constantly, and it is only by examining a large number of genuine signatures that it can be determined whether or not such changes are or are not normal features of the writing. If possible not less than five or six genuine signatures should always be examined and preferably double that number. In one case in which three cheques each for £E3000 had been forged 83 different genuine signatures were examined and these differed so much among themselves that it was impossible to prove that the suspected signatures were forged merely because certain tricks of writing were present or absent. The proof of forgery relied upon in this particular instance was the practical identity of the three forged signatures among themselves, which extended not only to the manner of

[1] See A. S. Osborn, *Questioned Documents*, 1929, pp. 421–32.

writing, the size of the letters and the space occupied by the signature, but even to the precise position of the signature upon the cheque, whereas no two genuine signatures exhibited such identity. It was noteworthy too that the writing of the forged signatures was bolder and freer from tremors and hesitancy than the genuine signatures, the forger being a better caligraphist than the original writer.

Traced signatures generally may be recognized (*a*) by their practical identity among themselves in size and form, (*b*) by the abnormal position of the shading and (*c*) sometimes by the remains of the tracing medium used. Out of a large number of genuine signatures occasionally it may be possible to find several that agree fairly closely, but even this is unusual and the agreement is never so close in all details as in the case of traced forgeries. On one occasion I examined twelve traced forgeries on cheques of the same signature, all of which were practically identical. Identity may be shown by means of measurements, by enlarged photographs, especially if these are taken through glass with ruled squares engraved on it, as suggested by Osborn,[1] and by superimposing negatives or positives on glass of photographic enlargements. The position of the shading is shown best by means of greatly enlarged photographs and as a rule it will be seen that it is in the wrong place, being present on some of the up-strokes and absent on some of the down-strokes, which indicates a slow drawing or painting with pen and ink over a tracing made sometimes upside down and it is impossible that such a result could be obtained from any natural writing habit. Remains of the tracing medium, such as pencil marks or colour derived from " carbon " duplicating paper, sometimes may be found by a microscopical examination and always should be searched for.[2]

Since a traced forgery is not the result of a natural writing habit any attempt to identify the writing as that of a particular person is useless unless there is collateral evidence: For example, the forger may have added, after the signature, the rank or function of the person whose signature has been forged, or a date, or the name of a place, and by comparing this writing with that of the suspected person it may be possible to prove the identity of the forger.

Arabic names as written are frequently very short and offer a very small field for comparison, and superficial differences between two Arabic signatures sometimes are due to one having been written with an Arabic reed pen and the other with an Arabic steel pen or with a European pen, or arise from the fact that one has been written with the paper placed flat on the table or other hard surface in the Western manner, while the other

[1] A. S. Osborn, *Questioned Documents*, 1929, p. 356.

[2] See O. Hilton, " The Detection of Forgery," in *Journal of Criminal Law and Criminology*, 30 (1939), pp. 568–599.

has been written with the paper held in the hand [1] or resting on the knee in the Eastern way. Sometimes, too, some of the letters are written over a second time or are touched up without any fraudulent intention. The greatest caution is necessary before giving a definite opinion regarding the genuineness or otherwise of a signature, and more particularly of an Arabic signature.

In handwriting cases the expert frequently is expected to examine and report upon a document in a few minutes or at most in a few hours when days may be necessary. Whenever such a request is made it should be explained that a superficial examination is not only worthless but may be misleading, and that the results at the best could only be very non-committal, and that no definite statement can be made unless adequate time for a thorough examination with proper appliances is allowed. The expert also should refuse to express any opinion on writing that he may be requested to examine in the witness-box.[2]

Graphology. By graphology is here meant the delineation of the character of a person from his or her handwriting. In this connexion, however, the word " character " may be ambiguous and sometimes it is employed in two entirely different senses, one meaning the character of the writer and the other the character (characteristic) of the writing. That the writing of every individual possesses certain special characteristics that belong to that individual only and to no one else is generally admitted and forms the basis of all handwriting examination. Thus the writing of different people may be recognized and differentiated, but so also may the work of different painters and sculptors. This does not mean that the character of a writer, any more than that of a painter or sculptor, can be interpreted from his handiwork, and although writing is the outcome of the personality of the individual it is a compound of so many factors that in my opinion it is impossible to translate it into terms of character, except sometimes in very broad outlines.

Charred Documents. The deciphering of charred documents became a matter of considerable importance during the war on account of the large number of documents partly consumed by fire caused by incendiary bombs or deliberately burned by the enemy when vacating a place, in order to destroy evidence. The first recorded systematic attempt in this direction, as pointed out by Mitchell,[3] appears to have been that of Sir Humphrey

[1] This sometimes can be proved from the presence of creases in the paper showing where it has been folded in order to hold it. These creases are very characteristic in appearance, and are never horizontal but always inclined across the surface of the paper.

[2] See p. 20.

[3] C. A. Mitchell, " The Deciphering of Scorched Documents," *Discovery*, 5 (1924), p. 336.

Davy, who in 1819 did a considerable amount of work on charred papyri recovered from the ruins of Herculaneum, the results of which he published.[1]

Partially burned documents may be in almost any condition, from being merely charred to consisting of a mass of small fragments of extremely fragile black and grey ash only just cohering together and liable to fall into smaller pieces when touched. The former present no great difficulty. The most satisfactory method of treatment is to place them between two sheets of glass, the edges of which are bound with *passe-partout*. An alternative method, though less satisfactory and not applicable except when the document is written or printed on one side only, is to mount them on thick paper or cardboard, which, however, involves the danger of injury during manipulation : it is done best by treating the mounting paper or cardboard over the area to be covered by the document with the adhesive, putting the document in position and placing on it until dry a sheet of thick glass. The problem of treatment when the document is in the condition of ash is two-fold, namely, first, to collect the remains, and second, to treat them so that they may be photographed, preserved and deciphered.

The first operation manifestly is to remove the ashes from the grate or stove, or wherever they may have been found, to a table, where they may be given the necessary treatment before transport to the laboratory for any further treatment required and for examination. This needs extremely careful manipulation, during which all currents of air must be avoided and, therefore, doors and windows must be closed, spectators, if any, must not walk about and, when the ashes have been retrieved, they must be removed to the table with the utmost care, being covered during transport with an inverted box or dish.

Since no two cases are alike, it is impossible to lay down any definite rules to govern the manner in which the salvage operations should be conducted, all that can be done being to mention a few guiding principles. Thus whenever possible, the ashes should be removed in a mass by gently inserting a sheet of thin cardboard or thin metal beneath them. If this is impossible, the next best plan is to remove them in layers in the same manner as suggested for the whole mass, and if this cannot be done, the separate fragments should be removed one by one, these being transferred to a small sheet of glass, thick paper or thin cardboard, by means of a soft brush, such as an artist's camel-hair brush. A slight agitation of the air in the immediate vicinity of the ash sometimes causes the fragments to rise slightly and facilitates their removal As a rule, forceps should not be used, except for the thicker and more solid pieces and, if employed, they should be of the kind with spatulate ends used by postage stamp collectors.

[1] H. Davy, " Some Observations and Experiments on the Papyri found in the Ruins of Herculaneum," *Phil. Trans. Roy. Soc.*, 1821, p. 191.

The ashes having been placed on a convenient table (still on the glass), paper or cardboard), the next stage is to separate and treat them so that they may be fitted together, photographed [1] and deciphered.

Although the separation and treatment can be carried out best in the expert's laboratory, this necessitates the packing and transport of the very fragile material, which, if possible, should be avoided, as it may result in some damage and even may cause total destruction. If, however, transport cannot be escaped, the ashes, on their support, should be placed on a sheet of soft paper (such as tissue paper) or thin cloth, which then is folded over at the sides and edges, without any attempt to make a secure parcel, and this is put in a box, which, if the transport is to be by hand, is loosely packed with cotton wool, or more firmly packed if the transport is to be by post. On no account should the cotton wool be allowed to come into contact with the ashes, as these would become entangled in the fibres from which they could not be disengaged easily.

The most difficult part of the whole operation is the separation of the fragile and generally badly distorted and shrunken fragments. Mitchell recommends soaking for several hours in hot water (about 40° C.) [2] when the separate pieces may be floated off one by one and transferred by means of a small sheet of glass or of celluloid to a larger glass sheet or to paper. I have found it very satisfactory to place the charred material in a wooden box on a perforated shelf, below which is a receptacle containing very hot water, the steam from which softens the brittle paper. The box should be lined with lead or zinc; with a well-fitting lid without hinges; the shelf should be of non-rusting wire gauze in a frame, and the water receptacle a shallow dish, such as a photographic developing dish. Sometimes thoroughly soaking the material in alcohol enables it to be separated, or occasionally this may be done dry. As an aid in the separation, which requires considerable patience and care, an artist's small sable or camel-hair brush, or a small ivory or bone paper-knife, often will be found useful.

For documents of parchment damaged by fire, Matthews [3] found steam, followed by dilute glycerine solution to prevent re-drying, the best medium for rendering the charred remains sufficiently pliable to allow of unfolding and other necessary manipulation. Donovan successfully treated parchment documents that had become dry, shrunken and hardened from heat by soaking them in water containing 1·2 per cent. of boric acid and 0·4 per cent. of caustic soda, after which, when separated from one another, they were stiffened with 10 per cent. formalin.[4]

[1] R. A. Reiss, *La Photographie Judiciaire*, 1903, pp. 108–10.
[2] C. A. Mitchell, *Documents and their Scientific Examination*, 1922, p. 83.
[3] C. G. Matthews, "Treatment of Parchments Damaged by Fire," *Analyst*, **49** (1924), p. 516.
[4] W. Donovan, *Annual Report for* 1931 *of the Dominion Laboratory, New Zealand* (*Analyst*, **58** (1933), pp. 405–6).

The next step varies with the nature of the documents. If these are written or printed on one side only, the pieces recovered should be fastened be means of an adhesive to a sheet of good quality white paper, but if there is writing or printing on both sides, tracing paper as transparent as possible should be chosen, or preferably the fragments should be placed between glass, since frequently it is impossible to see clearly through even the best tracing paper. When glass is employed an adhesive is not as a rule either necessary or desirable, though occasionally it may be useful in helping to flatten out the ash. Great care is necessary when placing the covering glass in position, as the material is very fragile and easily damaged or disturbed by the current of air caused by the operation, and when once in position the covering glass should not be moved again, but the two plates should be bound together by *passe-partout*. As a rule, it is neither possible nor necessary to arrange the fragments in order, all that is required being that they should be placed fairly close together, though not touching, and that they should be flat. Then they are photographed, a print is cut up, the pieces arranged in order, mounted flat on paper with an adhesive and the final result photographed.

A dilute (1 per cent.) solution of celluloid dissolved in acetone or in equal parts of acetone and amyl acetate has been found the most satisfactory adhesive,[1] and when the burnt fragments are thoroughly saturated [2] with the solution they may be flattened out by means of a soft brush or with the fingers. One great advantage of this adhesive is that, if necessary, it may be removed by means of acetone, quickly, easily and without damage.

No matter how unpromising the material may appear, it should be photographed and also should be examined under the ultra-violet rays, since characters barely visible often can be brought out clearly by one or other of these methods.

A photographic method of deciphering the writing on partly burnt documents devised by Davis [3] is used in America. In this method the fragments are placed in contact with the sensitized surface of a photographic plate and left in the dark room for a week or more,[4] after which the plate is developed in the usual manner, when the characters show white on a black background.

If the paper has writing or printing on one side only it is put, with this

[1] After the material has been dried, if wet.

[2] Unless thoroughly saturated they will be sticky and will adhere to the brush or fingers.

[3] R. Davis, *U.S. Bureau of Standards, Scientific Papers*, 1922, 18 (454), pp. 445–50, *Analyst*, 48 (1923), p. 241.

[4] Sellers (J. Clark Sellers, *Proceedings of the XVIIth Annual Convention of the Californian State Division, International Association for Identification*, 1932, p. 71) gives 9 days as the shortest time known to him and 6 weeks as the longest. If films are used two to three months are required.

side uppermost, on a table in the dark room and on it is placed a photographic plate with the emulsion side downwards. Often, however, documents are written or printed on both sides and in such cases, or unless it is known that the writing or printing is confined to one side, the burnt fragments should be placed on the sensitized surface of one photographic plate and covered with a second photographic plate having the sensitized surface downwards. A weight should be put on the plates, since burnt paper is always crinkled and unless pressed it does not make complete contact with the plate at every point. The faster the photographic plate, the quicker the action. Davis uses rapid or medium plates, Mitchell uses extra-rapid plates [1] and Sellers recommends panchromatic plates.[2] Davis points out that a longer time of contact is required if the burnt fragments have been exposed to the air, since recently burnt paper is much more active photographically than after it has been exposed for some time. This being so manifestly it is advisable that the photography should be carried out with as little delay as possible. Mitchell states that if the burning process has proceeded only a short way the action on the photographic plate is more rapid and complete than if the burning has reached, or nearly reached, the ash stage, when the action is very slow and in such cases, even using extra-rapid plates only a faint image of the writing is produced in ten days.

Tyrrell obtains good results by contact exposure of burned documents after a preliminary exposure to ultra-violet rays ; also by the use of a blue filter and by means of photography in oblique light.[3]

Taylor and Walls use chloral hydrate and photography and Jones uses photography alone.[4]

Photography by infra-red rays is often useful.

Murray obtained excellent results from documents written in ink by development with a 5 per cent. solution of silver nitrate as suggested by Superintendent Cherrill of New Scotland Yard.[5]

Written or printed characters on documents generally become invisible on that part of the paper that is merely blackened by charring and not completely reduced to the condition of ash, but these may be rendered visible again by careful burning still further until all that remains is a white or grey ash. To do this Mitchell [6] places the fragments between fine wire gauze, which is held with crucible tongs in a Bunsen flame. When the ash is

[1] C. A. Mitchell, " The Deciphering of Scorched Documents," *Discovery*, 5 (1924), p. 339.
[2] J. Clark Sellars, *op. cit.*, p. 69.
[3] J. F. Tyrrell, " The Decipherment of Charred Documents," *Journal of Criminal Law and Criminology*, 30 (1939), pp. 236–242.
[4] W. D. Taylor and H. J. Walls, *Nature*, 147 (1941), p. 417. See also G. A. Jones, *Nature*, 147 (1941), pp. 676–677.
[5] H. D. Murray, *Nature*, 148 (1941), p. 199.
[6] C. A. Mitchell, " The Examination of Charred Documents," *Analyst*, 50 (1925), pp. 174–81.

small in amount or not coherent, owing to the paper having been of good quality and free from loading material, it becomes necessary in order to make the further ashing a success, to treat the partially burnt fragments with a solution of aluminium acetate (10 per cent.) or thorium nitrate (20 per cent.) as suggested by Habermann.[1] The success of the operation depends upon the nature of the ink or pencil used originally, the best results being obtained with iron ink or blacklead (graphite) pencil and the worst with certain coloured pencils. The final ash is transferred to paper and coated with celluloid solution or with a transparent spirit varnish or placed between glass, and then is photographed. When the original writing has been made with an iron-gall ink a considerable amount of development often may be obtained by gently dropping on to the charred fragments a dilute solution of gallic acid or tannic acid before mounting. The nature of the ink or pencil used for writing often may be determined from the examination and testing of the residue left on the paper.[2] Baker describes how he was able to read the numbers on burnt currency notes.[3]

Illustrative Cases. 1. In an important land case in connexion with which one hundred and sixty-eight documents were examined, one hundred and sixty-three being forged, the methods of forgery adopted embraced practically all those known, some of the documents being entirely counterfeit, others being genuine documents tampered with in almost every possible manner, such as by the alteration of names and dates, the forging of signatures and seal impressions, the piecing together of parts of separate documents to make an entirely new document, the addition of forged endorsements, the burning, staining and mounting on other paper to hide signs of erasure, and the removal of the whole or part of the original writing and its replacement by other writing. In the case of the title deed of the land in dispute, which was a large document of between seventy and eighty lines containing some seventeen hundred words, the whole of the original writing, except the signatures, had been removed and replaced by other writing, this being rendered possible by the document having been written with carbon ink on a thick, glazed, parchment-like paper. Several interesting points in connexion with this document may be mentioned. In most deeds of this kind that have been examined it has been found that if the last line of writing normally would not have ended at the left-hand side of the paper or at the left-hand margin (Arabic writing is from right

[1] J. Habermann, *Zeitsch. anal. Chem.*, **48** (1909), pp. 729–50. Also *Chem. Abst.*, 1910, p. 1143, and *Analyst*, **35** (1910), p. 136.

[2] See " Restoring the Legibility of Printed Documents Damaged by Fire," *Annales de Médecine Légal*, Jan. 1936, p. 14. (*The Medico-Legal and Criminological Review*, **4** (1936), pp. 173–174.)

[3] G. W. Baker, *Report of the Government Analyst for the Year* 1938, *Palestine*; also *Analyst*, **65** (1940), p. 166.

to left) the last words had been stretched out, or the last letter elongated, so as to reach the edge of the paper or the margin, and immediately below the last line of writing and immediately above the signatures of the witnesses (the signature to a deed of this kind is at the top, but the witnesses sign at the bottom) a line was begun at the right-hand edge of the paper or at the right-hand margin and stretched right across the paper, ending with the word "*shehoud*" (witnesses); that is to say, the first letter of the word "*shehoud*" commenced as a long stroke at the other edge or margin of the paper. In one such document examined the line stretched continuously across the paper from one margin to the other, the word "*shehoud*" being absent, while in another document the writing was continued down almost to the bottom of the paper and no line was present, the signatures of the witnesses being in the margin. In only one other case among those examined (about a hundred altogether) was a line absent.

In the case of the document in question only part of the characteristic line alluded to was present, the missing portion being that on the right-hand side where the line normally should have begun, and the writing of the document, where the line was missing, extended down to the signatures. Parts of the missing portion of the line, however, were still faintly visible in places, and it was evident that the line at one time had extended across the paper in the usual way. The last few lines of writing too were crowded together unduly, although plenty of room existed below the signatures, which could mean only that this space was not available and that the writer therefore was limited to the space above, and hence that the signatures existed already at the time the writing was made.

The ink with which this document had been written was of a brown colour and possibly was sepia, though this could not be proved definitely. Sepia, however, was found in the house of one of the accused persons.

The original glazing of the paper had in large part disappeared and the paper had been scorched by fire in order to hide this and other suspicious indications.

2. A register was submitted for its age to be determined, it being suspected that an original register had been destroyed and another specially written one substituted. The book was new-looking and only slightly soiled, and had the appearance of having been used very little. The paper label on the back also was remarkably clean, and was partly detached. In the case of other similar registers the labels had come off at some time and had been re-fastened with extra gum, abundant traces of the operation being left. Nothing of the sort, however, had happened with the register in question. At the end of the register a sheet of foolscap paper had been inserted for use as an index. Other registers had been treated in a similar manner; but in this case the foolscap bore a dated water-mark that showed

it to be of a later issue than probably would have been the case had the register been the original one. A chemical examination of the ink proved it to be an ordinary iron ink, and provided abundant evidence that all approximately was of the same age, and that part of it at any rate was not as old as certain of the entries purported to be, some of which were dated more than twelve months previously: all the ink was fresh-looking and probably had been blotted, and in no case was it black, even to the naked eye, and it was all very blue when seen under the microscope.

3. A register that was presented in Court in support of a case being tried was found on examination to have been prepared specially. The dates of the entries extended over rather more than a year, and it was stated that the register had been kept and entered up in the office of a mill. The book, however, was clean and new-looking and free from dirt and dust, the ink was a bluish-green aniline ink and so could not be dated from chemical evidence, but it was the same colour throughout, and the writing was in the same hand and was all done with the same or a similar pen and showed signs of haste or fatigue towards the end. In two instances an entry that belonged to several lines below had been made and afterwards erased, and the dots under a word to indicate repetition, that occurred plentifully on every page, in some cases had been written vertically on a number of different lines at the same time, the ink showing progressively diminishing intensity of colour from the top to the bottom of a page.

4. In several instances letters enclosed in envelopes, that have been submitted in support of legal cases, have been found to be fraudulent, a genuine envelope with a postmark of the required date having been obtained, and a letter forged to accompany it. Forgeries of this kind generally may be exposed by a difference in the nature or age of the ink or by a difference in handwriting. In one case a grease stain, going through the envelope from front to back, did not occur on the letter; in other instances the envelopes had been mutilated in order to destroy the Post Office date mark.

5. In one case I gave evidence that a certain anonymous document written in Arabic with copying pencil was in the same handwriting as a document written in ink and signed with the name of one of the accused persons, who, however, denied all knowledge of either document and stated that even the signed document had not been written or signed by him. At the request of the prosecution the accused wrote the contents of the signed document from dictation in Court, once in pencil and once in ink. The writing on these dictated documents was so different from that both of the signed document and of the anonymous document that I was unable to prove that it was in the same hand. The accused, however, who was a student, had made a written application while under arrest to be allowed to sit for an examination and this had been allowed, and the application

and the examination papers were obtained and compared, with the result that the writing of all these was found to be identical with that both of the signed document and of the anonymous document and different from that done in Court. The explanation was that the accused, who naturally had been present when the significant features of his writing had been pointed out in evidence, had spent the intervening time (about a month) in practising a disguised hand, that differed considerably from his usual writing, and from which the normal characteristics had been eliminated.

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CHAPTER VI

DUST, DIRT, GLASS FRAGMENTS, STAINS AND MARKS

DIRT has been described as " matter in the wrong place," and it is the business of the expert to discover the place to which this matter when found in connexion with a crime, for example on a weapon or clothing or as particles of metal on a file, rightly belongs, and in so doing he may provide a valuable clue to the identity of the criminal. Since the chemist habitually detects ingredients that are present only to the extent of a few parts per million, and since the tenth, the hundredth and even the thousandth part of a milligram of certain substances can be determined quantitatively, the chemist, therefore, is peculiarly fitted to search for and examine dust, dirt, stains and marks. This, however, is seldom recognized except in the case of blood stains, with the result that much valuable evidence frequently is lost.

The subject of dust and dirt on clothing has been mentioned already in the chapter on Clothing,[1] and the methods of collecting the dust and dirt for examination have been given and need not further be discussed.

In Egypt a kind of dust frequently met with is sand, and the examination of this if found in connexion with a crime may prove useful, since the sand occurring in different localities may be of different appearance and composition, the river sand, for example, being siliceous, the desert sand frequently calcareous, the sand on the Mediterranean coast calcareous with numerous shell fragments, and the sand at Aswan largely granite detritus : dune sand too is characteristic.

It cannot be hoped that evidence of first-class importance will be obtained every time a specimen of dust is examined and in many instances the results will be negative, but even these sometimes may be of value. As examples of negative results, it may be mentioned that in one case the ashes of a fire were examined for the presence of calcined bones or other human remains, as the body of a murdered man was missing, but nothing of the sort was present, the body having been buried ; in another case a suspicious black deposit in thin flakes, that proved to be carbon, found adhering to the arm of a chair in a room where a murder was committed, could not be connected with the crime, and in two instances in which the finger nails of persons suspected of being concerned in the making of bombs were examined nothing incriminating was found.

Method of Examination. Dust and dirt should be examined first with a lens and then with a microscope. If there is a sufficient quantity, a portion should be heated to redness in a small dish or crucible to destroy

[1] See p. 56.

any organic matter present. The smell during burning should be noted and the inorganic residue left should be examined microscopically. As a rule the amount of dust and dirt available will not be sufficient for a quantitative chemical analysis, which is rarely necessary, but qualitative tests should be made and micro-chemical tests frequently will be found of service. Spectroscopic examination also sometimes is useful, especially for metals.[1] The spectroscope is such a common instrument in analytical laboratories nowadays that it need not be described. The emission spectrum of the unknown substance is taken and also a comparison spectrum of a mixture of known metals and the two spectra are examined side by side and may be photographed if required.

The subject of dust and dirt on boots and shoes has been referred already to [2] and it has been explained that the dirt should be examined with a lens before removal and that it is removed best by means of water and a soft brush. It is then just covered with water, while still in the dish, and examined carefully for such material as leaf and other vegetable tissue, fibres, seeds, small feathers or other easily recognizable objects, which should be picked out and examined further. Then it is dried and a qualitative analysis made to ascertain its essential nature, whether, for instance, it is clay or limestone.[3]

In the case of metal fragments adhering to a file, either these may be removed and tested by micro-chemical methods or tested *in situ*. In the latter case the particular test chosen should be one that gives a characteristic coloured compound and if the results obtained are dried and coated with transparent varnish, such as a solution of celluloid in acetone, the results of the tests may be preserved and produced in Court, which is much more effective than a mere statement of the findings.

Simple tests yielding coloured compounds for lead, silver, copper and antimony on a steel file are as follows [4]:

Lead. Add a drop of strong nitric acid; warm gently to drive off excess acid and when cool add a drop of a dilute solution of potassium iodide (excess of the reagent should be avoided as lead iodide is partly soluble in potassium iodide); a bright yellow-coloured compound indicates lead.

Silver. Add a drop of strong nitric acid; warm gently to drive off excess acid (silver chromate is soluble in nitric acid); when cool add a drop of dilute potassium chromate solution; a dark brownish-red compound indicates silver.

[1] S. Judd Lewis, "Quantitative Spectroscopy and its Analytical Applications," *Analyst*, **60** (1935), pp. 10–17: D. S. Smith, "The Use of the Spectroscope in Metallurgical Analysis," *Analyst*, **60** (1935), pp. 19–22.

[2] See p. 56.

[3] W. Schartz, "Dirt scraped from Shoes as a Means of Identification," *The American Journal of Police Science*, **1** (1930), pp. 55–9.

[4] All reagents should be applied by means of a capillary pipette.

Copper. Add a drop of strong nitric acid when a green colour will be formed if copper is present, then add a drop of strong ammonia solution ; a blue colour indicates copper.

Baker detected traces of copper on pruning shears as follows.[1] The shears were connected with the anode of a 6-volt battery in series with a 1-ampère lamp, and the cathode was connected with a platinum wire tipped with a compact fragment of cotton wool moistened with a saturated solution of potassium bromide in phosphoric acid, made by heating the acid with excess of the bromide and cooling. Contact for about a second between the moistened cotton wool and the suspected trace of copper produced a small purple-red stain on the cotton while contact with other parts produced no such stain.

Antimony. Add a drop of strong nitric acid ; warm gently to drive off excess acid ; when cool add a drop of a solution of sulphuretted hydrogen ; an orange-coloured compound indicates antimony.

Tin. There is no satisfactory test for tin on a steel file and any particles suspected to be tin should be removed carefully and tested by micro-chemical methods.

Glass Fragments. By means of the refractive index, the appearance when exposed to ultra-violet rays and particularly from the specific gravity, it is often possible to prove that fragments of broken glass have been derived from a particular source, the determination of the specific gravity being " the simplest and most discriminating " of the tests.[2 3 4 5 6 7 8]

The specific gravity is best determined by means of bromoform solution diluted with benzene (benzol) until the glass fragments remain suspended in the liquid, the density of this being found in the usual manner.

When glass fragments are submitted for examination, in addition to the physical properties mentioned, such features as the thickness of the glass, whether bevelled or not, and, if so, the angle and width of the bevel and any curvature present should be determined.

[1] G. W. Baker, " Electrolytic Application of the Hydrobromic Test for Copper," *Analyst*, **61** (1936), pp. 603–604.

[2] W. Donovan, " Identification of Glass Splinters," *Annual Report of the Dominion Laboratory, New Zealand*, 1932 ; *Analyst*, **59** (1934), p. 347.

[3] N. A. Marris, " Identification of Glass Splinters," *Analyst*, **59** (1934), pp. 686–7.

[4] C. T. Symons, " The Fluorescence Test : Ultra-Violet Light in Criminal Investigation," *The Police Journal*, **3** (1930), pp. 237–8.

[5] F. G. Tryhorn, " The Examination of Glass," *The Police Journal*, **12** (1939), pp. 301–318 ; *The Journal of Criminal Law and Criminology*, **30** (1939), pp. 404–419.

[6] P. Chavigny, " Identification of Glass in Motor-car Headlights," *The Police Journal*, **13** (1940), pp. 110–118.

[7] R. Malaval, " Identification of Glass in Motor-car Accidents," *Revue de Criminalistique*, 1930, p. 437.

[8] L. Gamble, D. Q. Burd and P. L. Kirk, " Glass Fragments as Evidence," *The Journal of Criminal Law and Criminology*, **33** (1943), pp. 416–421.

Stains and Marks. For the examination of stains and marks no general rules can be laid down, since no two cases are alike, but each must be made the subject of special study and individual treatment. If possible, the stain or mark should be examined under the ultra-violet rays as this may supply useful information.

The testing of stains and marks does not as a rule obliterate or destroy them, but if this seems likely to happen they should be photographed first so that a permanent record may be preserved for future reference or for production in Court. In any case a photograph will be helpful, since it is difficult to convey an exact description of the appearance of a stain or mark by means of a written account. In the case of small stains and marks any photograph taken should be enlarged.

Blood Stains.[1] *Marks on Projectiles.*[2] *Stains and Marks on Clothing.*[3] These are dealt with in other connexions.

Stains and Marks on Documents. Stains and marks on documents sometimes are of considerable value as evidence. Thus it may happen that the post office cancellation and date marks on envelopes are impressed so vigorously that the outlines of them are indented on the letters inside. In several cases it has been possible to prove that the contents of certain envelopes had been through the post previously, since they bore marks made by a post office stamp that did not correspond to any on the existing envelope. In one instance the marks were on an inner sheet only and hence the paper had been folded differently on the previous occasion. Also, if a particular post office mark shows through on to the far side of the envelope to that on which it was impressed, as occasionally happens, any letter inside also must have been marked, and hence in such a case a letter, folded sufficiently large to fill or almost fill the envelope, which does not show the mark in question, cannot have been in the envelope at the time it was stamped. In one case the fact that a certain grease stain that occurred on both the back and front of an envelope did not exist on a letter that was alleged to have been in the envelope, strengthened other evidence that the letter was a forgery. Sometimes stains of ink or colour on a document enable a connexion to be established between one document and another or between a document and a particular person.

Blotting paper sometimes shows traces of writing that may prove valuable evidence and such writing often may be deciphered by the examination of its reflection in a mirror, or if held against a window or other source of light and examined from the reverse side. If any writing likely to be of importance is seen a photograph should be taken and an enlargement made. On "carbon" duplicating paper, too, especially if new, part, or even the

[1] See p. 23. [2] See pp. 218–232. [3] See pp. 50–56.

whole, of a document typed sometimes may be legible if the paper is examined by means of a mirror (for which purpose it should be pinned to a drawing board or to a piece of cardboard) or if placed between two sheets of glass and photographed by transmitted light.

Stains and Marks on the Person. In addition to marks on the person such as those resulting from wounds, operations or disease, the examination and identification of which are matters for the medical man, or of tattoo marks or of marks on the hand indicating a particular occupation, both of which fall within the province of the detective, there may be stains that should be examined and tested by the chemist, such as those caused by acid, dyes, photographic reagents, ink, grease, tar and many other substances. If stains are found, the position and appearance should be noted: then if possible they should be removed by some solvent, and analysed. The solvent, using the minimum amount possible, is applied best, as a rule, by means of swabs of cotton wool, except in the case of blood stains.[1] Sometimes very small swabs formed by twisting a little cotton wool round a plain undyed wooden match-stick will be found useful. From the appearance of the stain its nature frequently may be surmised and the particular kind of solvent to apply will then generally be known. Thus stains of iodine may be removed by sodium thiosulphate, stains of silver nitrate by potassium cyanide, stains of picric acid or dye stains by alcohol or water. If the nature of the stain is not known, water should be tried first and then alcohol and afterwards other organic solvents, for example petroleum spirit, the object being of course not simply to remove the stain but to remove it in such a condition that it may be tested. For this reason many reagents that remove stains such as bleaching powder cannot be employed. It is not possible, however, to dissolve off all stains; thus for example tobacco stains and those caused by nitric acid cannot be removed. Picric acid stains also are difficult to remove entirely, although when fresh a little may be dissolved off with alcohol. It has been found that even considerable stains of picric acid on the hands disappeared in two days and that stains on the nails sometimes persisted for about a week. Nitric acid stains on the skin remain until the skin peels off and on the nails such stains persist until the nail grows sufficiently long for them to be cut off, which may take several months. The solution obtained by the removal of the stain should be squeezed from the cotton wool and examined chemically in the way indicated by its probable nature.

In one case that occurred in Egypt when a man's hands were being examined, purple stains similar to those produced by a gold solution were noticed, and it was proved subsequently that the man had been engaged in "sweating" sovereigns by means of aqua regia. In another case a child

[1] See p. 25-26.

was poisoned by means of silver nitrate and a stain of silver nitrate was found on the hand of the accused person. Silver nitrate, too, found on the front of a white jacket helped to prove that the owner had used silver nitrate marking ink for some clothes, about the ownership of which there was a dispute.

In connexion with stains and marks on the person, the faking of the colour of animals, particularly horses and dogs by dyeing the hair, may be mentioned. As a rule the colour employed is an aniline dye that is soluble in alcohol and so may be removed by this reagent.

Paint, Enamel and Varnish Marks. Traces of paint on tools that have been used for forcing open doors, windows or safes may be helpful in connecting the crime with a person in whose possession the tool has been found.

Also, traces of enamel from a motor car may be transferred to a bicycle, to another car or to a person that has been hit by the car in an accident, and from the examination of such traces the particular car from which they have been derived sometimes may be identified.

Paint smears on clothing have been dealt with previously.[1]

As the traces referred to usually are very small the only satisfactory method of analysis is by means of micro-analysis or by a spectroscope.[2]

Imprints of Tools and Weapons. In connexion with dust, dirt, stains and marks, the identification of metal tools and implements, such as chisels, saws, hammers, axes and knives, from the marks left on objects on which they have been used may be mentioned.

The principle is the same as that employed for the identification of bullets and fired cartridge cases by means of the marks left on them by the weapon used.

The edges of the blades of tools and implements and the heads of hammers are never perfect, even when new, and after much use they bear the marks of uneven wear, accident and of sharpening in the case of blades, and, even if apparently in good condition to the naked eye, they will show tiny imperfections when examined microscopically. All such marks and irregularities are individual and characteristic and the marks of them may be left on an object, particularly a wooden object,[3] on which the tool or implement has been used.

In order to identify any imprints found and to connect them with a specific tool or implement these imprints and others made experimentally with the suspected tool or implement must be examined and compared

[1] See p. 56.

[2] See also H. T. S. Britton, " Paint Marks and Their Importance in the Detection of Crime," *The Police Journal*, **12** (1939), pp. 205–209.

[3] G. S. Sansom, " Cuts on Wood," *The Police Journal*, **6** (1933), pp. 407–410.

microscopically and also carefully measured with instruments of precision by one accustomed to such work and, in order to make the evidence clear to others, photomicrographs of the imprints must be taken and enlarged, and if possible casts should be taken of the imprints, for which purpose Wood's metal will be found satisfactory.[1]

In a similar manner human teeth, and hence a particular person, sometimes may be identified by means of the marks left on objects bitten.

The microscopical examination (as distinguished from a chemical analysis) of the metal found in connexion with a crime sometimes may be helpful in fixing the crime on a particular person if identical features are found in any metal that can be connected with him. This examination consists in polishing the metal carefully and thoroughly in order to remove all scratches ; cleaning it from grease ; etching it with a suitable solution, the nature of which depends upon the kind of metal,[2] and then examining it microscopically for the crystalline structure, which varies, not only with the composition of the metal, but also with the heat and mechanical treatment to which it has been subjected. Any inclusions, such as slag, should also be noted, as often they are characteristic.

Wood. When marks on wood are identified as having been made with a particular tool, a determination of the nature of the wood itself is sometimes required, since the piece marked may be part of an object with which it is necessary to connect it. The only certain method of identifying wood is by an expert examination of its structure with a microscope. Sometimes, too, wood found in connexion with a crime may be shown to be identical with, or as having formed part of, other wood found in possession of a suspected person. The most striking example of wood identification in a criminal case is that of the ladder used in kidnapping the Lindbergh baby, some of the wood of which was proved to have formed part of a floor board in the attic of the accused person.[3]

Illustrative Cases. 1. Sand found in the pockets of the waistcoat mentioned in connexion with the subject of Clothing proved to be extremely fine quartz sand with well rounded grains of uniform size similar to dune sand, from which it was concluded that the wearer of the waistcoat had been in a locality where there were sand dunes.

2. Sand taken from the barrel of a gun was proved to be identical with the sand from the place where a crime had been committed, and of which the owner of the gun was suspected. The value of this fact, however, was discounted by the further fact that similar sand could be found in many

[1] See p. 201. Also J. V. Collins, *Analyst*, **61** (1936), p. 417.
[2] G. W. Pirk. See Bibliography.
[3] I. A. Koehler, " Technique used in Tracing the Lindbergh Kidnapping Ladder," (*a*) *The Journal of Criminal Law and Criminology*, **27** (1937), pp. 712–714 ; (*b*) *The Police Journal*, **10** (1937), pp. 356–365.

other localities, but in connexion with the particular circumstances of the case the fact was helpful.

3. Sand taken from the stomach and duodenum of a drowned man was examined and, as the quantity available was very small, only a microscopical examination was possible. The material was found to consist essentially of colourless grains, all very angular and many having definite crystalline form that proved to be selenite: there was an absence of quartz, but on one slide there was part of a diatom. The presence of selenite in large proportion and the absence of quartz seemed to preclude the Nile valley and suggested the northern shores of Egypt. It was probable therefore that the man was drowned off the coast where his body was found and that he had not been transported there after having been killed elsewhere, as was thought at first might possibly have been the case.

4. In several cases of counterfeit coining the fact that the working parts of machines seized on the premises of the accused persons were well oiled and were free from accumulated dust and dirt has made it probable that these machines had been used recently.

5. A safe had been robbed, the door having been bored through, and some of the finely powdered material used as a fireproof packing between the two walls of the safe was scattered about the room. This was found to be entirely mineral, to be free from fibres and organic matter, and to contain a number of small rounded particles of various colours, that had been fused and were very characteristic, and it consisted probably of finely powdered furnace slag. Some dust found on the clothes and between the fingers of two persons suspected of the robbery was identified as consisting of this same material and the men were convicted.

6. In a coining case a tiny particle of metal, similar in composition to that used for making the counterfeit coins, was found on a file in the house of one of the accused persons.

7. In connexion with various shooting outrages, revolver cartridges seized were found to have been made by filing down the brass cases of military rifle ammunition, probably stolen, and inserting in place of the cupro-nickel coated bullets, which do not readily lend themselves to alteration, lead bullets hammered and filed to fit. A file also was seized on which were tiny metallic particles some of which proved to be brass and others lead.

8. Certain market gardeners, who cultivated land alongside one of the principal roads leading out of Alexandria, brought an action against the Municipality for alleged damage done to their crops by dust containing tar derived from the road. It was proved, however, that the damage complained of was largely due to insect pests (*Thrips* and *Aphides*) and that the black patches on the plants pointed out as evidence of tar were not tar, but black fungus growths on the sticky excretion from the *Aphides*.

9. In a bomb case stains in a cardboard cigarette-box, which on testing were found to be due to sulphuric acid, were sufficient to prove that the box had been employed to carry certain small bottles of sulphuric acid which was used in the bombs.

10. Marks on miscellaneous objects examined included (*a*) a very faint indented impression on paper made by pencil writing on a sheet above, which could not be deciphered; (*b*) an almost obliterated name and number in blacklead pencil on a web belt, the name and part of the number being deciphered, the use of side-lighting and of a brown glass screen being very helpful; (*c*) an almost obliterated name inside an army cap, which was deciphered after grease had been removed by petrol; (*d*) obliterated stamped lettering on twelve stolen spoons, which was deciphered a little on one and a little on another; (*e*) obliterated marks on two motor tyres, which were not deciphered, but which from circumstantial evidence probably were the British Army War Department mark, and (*f*) an obliterated number on an aluminium nameplate from a stolen camera.

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[1] This, although so old, is still useful and is mentioned because it is the latest English edition that can be traced, although there are more recent German editions, for example Behrens-Kley, *Mikrochemische Analyse*, 1915.

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CHAPTER VII

EXPLOSIVES AND EXPLOSIONS

CASES having reference to explosives and explosions submitted to the chemico-legal expert generally concern high explosives used or intended to be used for criminal purposes, or are connected with explosions in cases where crime is suspected, but may relate to accidental explosions in order that their cause may be determined and the blame, if any, rightly attributed.

The expert should visit and examine the scene of the explosion at the earliest possible moment, since if there is any subsequent trial he is almost certain to be questioned about the manner in which the explosion occurred and the extent of the damage caused. It is better also whenever possible that the expert should assist the police in collecting the debris and in searching for indications likely to be useful in proving the nature of the explosive employed. The significance of traces of various substances will be described later.

In the case of unexploded bombs and other explosives usually it is preferable that the expert should examine the objects where they are found rather than that they should be sent to him.

Bombs. Bombs have been a favourite method of assassination for many years, but they became much more common after the war of 1914-18 when large numbers were employed by the various armies and the knowledge of their construction and use became widespread.

Bombs vary considerably in size, shape, nature of envelope, nature of explosive and mode of initiating the explosion.

The examination of live bombs always is attended with danger, and all possible precautions should be adopted to avoid accidents. It might seem that the best preliminary examination of a suspected bomb would be to have a radiograph taken, since in many cases the nature and disposition of the contents would become plainly visible.[1] To radiograph anything, however, necessitates a certain amount of handling, which often is inadvisable when dealing with bombs of unknown composition. Also, radiography takes time, and if the bomb were a delayed action one, the time would be better employed in rendering it harmless or in destroying it. In the case of a series of bomb outrages the later bombs probably will be of the same type as the earlier ones, and hence by studying these a good idea of the nature and disposition of the explosive material may be obtained that will be of great assistance in opening any live bombs found subsequently.

[1] Several instructive reproductions of such radiographs are given by Brouardel. P. Brouardel, *Les Explosifs et les Explosions*, 1897.

Only amateur-made bombs will be considered, since the removal, destruction, or the rendering harmless of naval, military or air force bombs is a very specialized undertaking, which should be left to experts.

It is impossible to lay down any but very general rules to be applied to the opening of bombs, since these are of so many different kinds, each of which needs special precautions, and it would be impossible to describe the various types without supplying information that might be of service to criminals. The following guiding principles, however, may be helpful:

(1) On no account to shake or invert a bomb.

(2) If there is a lighted fuse, this sometimes may be extinguished before the bomb explodes, which may be done by stamping it out, by cutting off the lighted end, or by means of water. Since many explosives are comparatively safe when wet a general impression exists that the best way of treating a bomb in order to render it harmless is to place it in water, but such a method should not be adopted indiscriminately, since bombs in which metallic potassium or sodium is used, or even those containing sulphuric acid, might be exploded in this manner; water, however, may be useful in putting out a lighted fuse attached to a bomb. Many bomb cases are waterproof.

(3) To place the bomb on a solidly constructed table or other flat surface and, unless it is of a shape that will not stand upright, to keep it absolutely vertical.

(4) To examine or open the bomb in such a place and under such conditions that an explosion would cause the minimum damage to life or property, the operator being sheltered behind a specially constructed steel shield or protected by sandbags.

(5) To study carefully the probable effect of each step before it is taken.

(6) To work slowly and gently, using as little force as possible.

(7) If a detonator or percussion cap is visible, this should be removed the first thing whenever possible.

(8) If any screws are visible near the top, these should be taken out and, if the cover is screwed on, it should be unscrewed carefully. Before replacing a screwed cover, especially if the explosive is a potassium chlorate mixture, the screw should be brushed with a small stiff brush to remove any particles of the explosive that may have lodged in the threads and which if left would be liable to explode by the friction caused by reclosing.

(9) When the bomb is opened if a glass bottle or tube or wax receptacle is seen, this almost certainly will contain sulphuric acid. If this is open at the top, which, if glass, it probably will be, it should be corked securely (taking care not to break it by corking too tightly)

before either the bottle, tube or other contents of the bomb are removed. If the acid is contained in a closed glass tube, this probably will be very fragile, and may contain a lead weight at the bottom, hence great care is necessary in handling it. Sometimes it is preferable and possible to remove the rest of the contents, leaving the acid to the last.

(10) If the package suspected to be a bomb is tied with string or fastened with wire, and if this is not all visible, but if a part enters the package, this particular piece must not be untied or cut, since it might hold up a hammer or weight which when released would explode the bomb. The string or wire must not be pulled, since it might be attached to a glass tube containing acid, which would thus be broken.

(11) If when the bomb is opened a spring is seen, this probably will be attached to a hammer, the fall of which would explode the bomb, and the spring therefore should not be released until something is interposed between the hammer and the object below, or until this object, which may be a percussion cap or a tube of acid, is removed.

(12) Clockwork mechanism for firing a bomb generally can be detected by the sound. Such a bomb must be so handled as to prevent the hammer from striking any explosive composition or any glass vessel containing acid that may be present, and anything of this sort should be removed carefully.

(13) As a last resort the bomb should be taken to a large vacant plot of ground and exploded by shooting at it from a safe distance, and the fragments examined. It is stated[1] that in Paris all bombs are crushed in a hydraulic press, the fragments afterwards being collected and examined and that the operation is carried out in a lightly constructed wooden building situated on vacant land and surrounded by an earthen embankment and a high masonry wall.

Several methods of opening bombs are mentioned in various books, of which I have had no personal experience. One of these is very ingenious, but is applicable only to metal receptacles that are closed by solder. This method consists in fixing the bomb in a deep stone basin into which mercury is poured until the basin is full, when the sides, bottom and cover of the receptacle fall apart, the solder being dissolved by the mercury. Another method recommended when dealing with thin metal casings of which the cover is not soldered or rivetted, is to place the bomb between two vertical supports, one of which is fixed and the other movable, and the latter, being

[1] "Studying the Anarchists' Bomb Scientifically," *Sci. Amer.*, **105**, 100, *Chemical Abstracts*, 1911, p. 3341.

operated from a distance, then is pressed gradually against the casing in order to deform it, when the cover becomes loosened and may be removed easily. A third method is to cover the bomb with an acid-proof varnish, except a patch at the side, above which it is further protected by a coating of rubber; then it is immersed up to the level of the patch in carbon tetrachloride and above this up to the top of the bomb in dilute acid or alkali, according to the nature of the metal of the case, and subjected to a weak electric current, the whole being put in a safe place surrounded by sandbags. The metal of the patch is dissolved away gradually and the contents falling into the carbon tetrachloride are removed from the action of the acid.

None of these methods would be suitable for bombs of the type employed in Egypt during 1919-22, which will be described later. As it was thought that valuable information, that possibly might lead to the discovery of the criminals, might be obtained by opening certain live bombs that were found, this was done by hand. Ordinarily, however, such bombs are best dealt with by covering them with sandbags and exploding them *in situ* by means of a detonator and high explosive cartridge, after evacuating the premises, since their removal always must be attended with danger. Sometimes dummy bombs are employed by practical jokers in order to create a scare, but until objects suspected to be of this nature have been proved to be harmless they should be handled with the usual precautions. In some few instances the nature of the material employed may lead to the discovery of the perpetrators of the joke.

In the examination of a bomb, its appearance, nature and construction should be noted carefully and described, and the bomb, after having been opened, should be weighed and measured and the explosive material weighed and analysed. Fragments of bombs that have exploded also should be weighed and measured, since details concerning the size and capacity of the bomb and the thickness of the metal are likely to be required subsequently, either for comparison of one bomb with another or in order to answer questions raised in Court or to meet arguments advanced by the defence if the case is tried. All fragments should be examined carefully for traces of the explosive. In the case of amateur-made bombs, a metallographic analysis may enable the source of some of the metal parts to be identified.[1]

Cartridges. Cartridges of dynamite, gelignite or similar material should be weighed and measured and the nature of the explosive material determined, and the wrappers should be examined for indications such as the manufacturer's name or other marks of origin. In several cases connected with explosives that have been investigated, the size, weight and

[1] J. H. Mathews, "Metallographic Analysis in Crime Detection," *American Journal of Police Science*, 1 (1930), pp. 439–43.

composition of blasting gelatine and dynamite proved that these materials were not of the kind that alone could be imported legally into Egypt and therefore that they were contraband.

Disposal of Residues. One difficulty the expert will have in dealing with explosives is that of getting rid of the residues of the samples. In the case of materials such as blasting gelatine, gelignite, dynamite and cordite, the materials should be placed in an open space, saturated with petroleum spirit and burned, the fire being started by means of a fuse, care being taken so to arrange and light the train that the flame will travel against the wind. Black powder and potassium chlorate explosives may be rendered harmless by dissolving out the soluble ingredients with water. Nitroglycerine may be destroyed by means of an alcoholic solution of sodium hydroxide, but is better burned in small quantities at a time. Detonators cannot be destroyed with safety, and should be taken out to sea and thrown into deep water.

Traces of Explosive left after Explosion. When a bomb, especially an amateur-made one, explodes, it may happen that the whole amount of the explosive is not destroyed, but that particles of one or more of the ingredients are scattered about in an unchanged condition, and even when the explosive is destroyed entirely, the solid products of its decomposition remain and may be found if careful search is made. Naturally, also, any metal such as wire, parts of clockwork, or other mechanism should be collected and examined. Celluloid may indicate a washer that has been eaten through by acetone in order to free a metal spring, or a diaphragm keeping a liquid and solid apart. The following examples may be mentioned.

Picric Acid. When this is exploded in an amateur-made bomb frequently it is not all consumed, but a little is scattered about and yellow stains often may be found on the fragments of the bomb and on objects that have been hit, instances of which have been given when dealing with stains on clothes.[1] In one instance a piece of rusty tinned iron (part of the case of a bomb) which was found about a month after the crime (having meanwhile been exposed to the weather) gave tests for picric acid.

Sulphuric Acid. In cases where this acid has been employed for initiating an explosion, traces of free acid may be found on pieces of the glass or wax acid-container; on parts of the metal holder of this container; on parts of the bomb and on objects that have been hit, thus on one occasion small splashes of sulphuric acid were present on a motor car that had been damaged.

Potassium Chloride. This compound is produced when potassium chlorate is exploded or burned and, if found on debris resulting from an explosion, it may support other evidence that potassium chlorate was present

[1] See p. 60.

originally, though by itself it is not a proof of this, since some explosives contain potassium chloride. In one instance after an explosion of a bomb, a small quantity of unchanged potassium chlorate was found in the depression of the head of a screw in the metal bomb case.

Sugar and Sulphur. Although there was reason to believe that one or both of these substances may have been among the ingredients of the explosive mixture in certain bombs used in Egypt, since they were found in similar unexploded bombs and in connexion with partly-made bombs, no evidence of their presence was ever discovered after an explosion. This, however, is to be expected on account of the gaseous nature of the products of their combustion. It is not safe, therefore, to assume that sugar or sulphur has not been used because the evidence of their presence is negative. Sometimes sulphide of arsenic is used with potassium chlorate instead of, or in addition to, sulphur.[1]

Other Ingredients. Since the number and variety of ingredients that may be used is very large, it is impossible to enumerate all the solid products that may be left after an explosion, but all are significant, either of particular explosives or of certain types of explosives, one of the most characteristic being kieselguhr, an infusorial earth employed as an absorbent for nitroglycerine in certain kinds of dynamite. Spectroscopic analysis often may be useful.

The presence of powdered metallic aluminium, or aluminium oxide, may indicate either the use of metallic aluminium as an incendiary material, or the use of thermit, which is a mixture of aluminium powder and iron oxide, often used in incendiary bombs. Iron oxide, or fused iron, may also indicate thermit.

Magnesium oxide, which was found by me on one occasion, may result from the burning of metallic magnesium used as an incendiary material.

In one instance a delayed-action bomb examined by me, which had been exploded by machine-gun fire, still contained a considerable amount of unaltered TNT (trinitrotoluene), which consists generally either of a mass of small crystals of a pale yellow colour, or of a light-brown fused mass, which may be very hard. It gives a blood-red colour with alcoholic potassium hydroxide solution and with alcoholic ammonia solution.

In another case, a number of stolen military hand grenades, used by political agitators, either failed to explode, or exploded only partially, because the ammonium nitrate of the filling mixture was damp, owing to the grenades having been stored in a damp place.

Analysis of Explosives. As a rule all that is necessary in the way of chemical analysis of explosives is a qualitative testing to ascertain the

[1] See footnote 1, p. 53.

nature of the material. Occasionally, however, a quantitative analysis may be required, as for example in order to identify an explosive used for criminal purposes with some other explosive that is possibly the source from which the quantity used has been obtained, or when it is thought that the results of a complete analysis might indicate the place or country of origin, or when the explosive is of amateur make and the details of its composition might be useful. High explosives are of so many possible kinds that no attempt will be made to give methods of analysis which may be found described in the standard textbooks on the subject. The weight of the explosive or of the several ingredients of a mixture should be determined whenever possible.

In the case of a mixture containing picric acid, potassium chlorate and possibly sugar and sulphur, the picric acid is first dissolved out by treatment with absolute alcohol and tested in the manner already described.[1] The residue is dried and if sulphur is present it may be detected by an examination with a lens or low-power microscope and may be dissolved out by treatment with carbon disulphide and recognized by the usual tests. As it is advisable to remove any sugar present before testing for potassium chlorate, and as this is very soluble in cold water, whereas potassium chlorate is not very soluble, the material should be extracted with a minimum amount of cold water and the solution examined for sugar, which may be detected and estimated by means of Fehling's solution and also may be detected by the taste and, after evaporating off the water, by the smell of caramel given off on burning and by the black carbonaceous mass left. The residue is dried and tested for potassium chlorate by means of strong sulphuric acid, which liberates chlorine dioxide, recognized by its characteristic smell, its greenish-yellow colour and by the bright yellow colour imparted to the acid. In this test, heat must be avoided and only a very small quantity of the material and of the acid used, otherwise an explosion may result, the reaction being very violent. The presence of chlorate may be confirmed (*a*) by adding silver nitrate to a solution, filtering off any chloride precipitated, then reducing the chlorate to chloride by means of nitric acid and formaldehyde, or by sulphur dioxide gas, again adding silver nitrate and allowing the precipitate formed to settle and testing its solubility in ammonia, after decanting off the liquid, or (*b*) by means of a solution of aniline hydrochloride in strong hydrochloric acid, or of aniline and hydrochloric acid, which when heated with chlorates produce a blue to green colour, or (*c*) by means of ammonium thiocyanate.[2] Potassium is tested for best by the flame reaction and potassium chloride by testing for potassium in the

[1] See p. 53.

[2] H. R. Offord, *Industrial and Engineering Chemistry, Anal. edition*, 1935, **7**, pp. 92–95; *Analyst*, **60** (1935), pp. 341–342.

flame and by applying the usual tests for chloride. The tests for sulphuric acid have been given already.[1]

Gelignite and similar explosive material should be cut with a horn or bone knife and never with steel, and care should be taken not to handle an explosive containing nitroglycerine more than is absolutely necessary, otherwise the very unpleasant symptoms of nitroglycerine poisoning (violent headache, profuse perspiration, vomiting and diarrhœa) probably will be experienced.

Explosion of Sulphuric Acid Drums. Explosions sometimes occur with iron drums containing sulphuric acid. This substance, if strong and free from nitrous acid, may be stored and carried in iron receptacles without danger, the stronger the acid, as a rule, provided it is pure, the less the danger, but if the acid is impure or below a certain strength, it acts chemically upon the iron, thus weakening the drum and at the same time producing gas (hydrogen) that eventually may be under sufficient pressure to rupture the drum, or even if this does not happen, the pressure may be sufficient to eject some of the acid to a distance and cause damage when the drum is being opened. Instances of such accidents have occurred in Egypt, as a result of which injury both to persons and property has taken place. In one case a drum was blown through the roof of a store room and in another case acid was projected to a height of about eight feet. The presence of hydrogen, too, may cause an explosion if a flame is used to free a bung or plug that has stuck. The principal points for the chemist to determine are, first, the nature, strength and purity of the acid; second, the amount of corrosion inside the drum, from which the extent of the action of the acid on the iron may be judged; third, the quality of the drum; and fourth, the extent to which the drum was filled originally, if it be possible to ascertain this from any marks on the inside or otherwise, since in several instances in Egypt drums filled too full for such a hot climate have exploded when left in the sun on a railway platform or in a train at a siding, the explosion having been caused largely by the expansion of the drum contents (both acid and evolved gas) due to the heat.

Illustrative Cases. 1. The bomb thrown at H.H. the late Sultan Hussein of Egypt in 1915, which fortunately did not explode, consisted of a mass of gelignite weighing 338 grams, into which were inserted a large number of the iron studs used for fastening the bands of cotton bales, also a detonator and fuse, the whole being wrapped in a newspaper and then in thin pliable leather to make it resemble a harmless ball. The failure of this bomb to explode was due to the fact that a small amount of sawdust had been left in the detonator,[2] and although the fuse burned through, the

[1] See p. 52.

[2] Detonators are usually packed in sawdust.

amount of sawdust was sufficient to prevent the flame from reaching the fulminate. A second and similar bomb was found in the room from the window of which the first was thrown, but in this case there was no sawdust in the detonator, and in all probability therefore the second bomb would have exploded had it been used instead of the first.

In the case of these bombs the composition and weight of the gelignite made it probable that each had been made by massing together eight of the large size of blasting cartridges, and pieces of parchment paper, such as is used for wrapping gelignite cartridges, remained embedded in the mass: these were all cut out and examined, but unfortunately there was no inscription on them. The exact size of the bomb proved of importance, since one of the questions raised by the defence during the trial was whether it was possible to pass the bomb through a certain opening in a shutter, it having been proved that the shutters of the window from which the bomb was stated to have been thrown were only partly open.

2. In the case of the bombs thrown at various Egyptian Ministers during 1919 and 1920 it was possible from an examination of the fragments to say exactly what the bombs had been. The general type consisted of a cylindrical iron case in two parts, a receptacle and a screwed on cover, containing iron nuts or pieces of iron rod to act as projectiles, though the fragments of the casing itself were much more dangerous and frequently weighed between 100 and 200 grams each, in one instance a single piece weighing 362 grams. The explosive was a mixture of picric acid and potassium chlorate with probably, in some instances at least, sugar or sulphur or both and possibly occasionally match heads. There was not any detonator or fuse, the explosion being initiated by the action of strong sulphuric acid contained in a small open glass tube or bottle fixed upright in the case and the explosion took place when the bomb was inverted and not on impact, most of the bombs exploding in the air. In one instance a much larger bomb, seized by the police, was intended to produce an explosion on board a ship. The sulphuric acid was contained in a small open tube attached to the large hand of a clock, so that when the hand had moved to a certain position the acid would drop on the top end of a small copper tube, open at both ends, which contained potassium chlorate or a potassium chlorate mixture, and which passed through the bomb cover. The exact nature of the contents of the tube were not determined, since it exploded while being removed. Certain other bombs seized by the police were without sulphuric acid and possibly were intended to have been exploded by means of a detonator or fuse.

3. One case was that of the explosion of two adjoining stores for explosives, and naturally those interested in one store claimed that the explosion had started in the other. It was eventually proved to be due to the presence

in one of the stores of a high explosive that had formed part of the cargo of a boat that had been wrecked on the Nile in the Sudan, retrieved, dried in the sun and sent to Cairo, where it had been stored for several years and it was (as was only to be expected) in a very deteriorated and unstable condition.

4. Another case was that of the explosion of a store containing blasting gelatine, gelignite, detonators and fuses to be used for mining and quarrying. The cause of the accident was again spontaneous decomposition, the explosives having been stored badly, the fresh material received having been placed on top of the old and then used first, with the result that a residuum of old stock had been left for several years and, as the store was situated in Upper Egypt, the temperature to which it had been subjected during the summer had been considerable.

5. In a case in which one child was killed and several others injured, the debris collected comprised pieces of a modern high-explosive shell, a mallet and a chisel, and it seemed evident that the children had found the shell and had attempted to open it.

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CHAPTER VIII

FIBRES; WOVEN FABRICS; STRING AND ROPE

Fibres

A few loose fibres may be found in connexion with a crime and recognition of their nature may establish the innocence or guilt of a suspected person.

Fibres fall naturally into two classes, those of animal origin and those of vegetable origin, the former being either animal hairs or silk and the latter vegetable hairs or fibres from the stems, leaves or fruit of certain plants.

There are few subjects that will repay the chemico-legal expert better than the study of the microscopical appearance of fibres and certainty of recognition can be attained only by long practice. The published illustrations of the structure of fibres, although sometimes helpful, on the whole are disappointing and anyone relying upon a book illustration and not on his own experience is apt to be misled. The only certain method of recognition is by means of careful comparison with other fibres known to be genuine. The expert should make himself acquainted not only with the microscopical appearance of the hair of the ordinary common animals and of fibres used for woven fabrics, but also he should be able to recognize most of the principal textile fibres of commerce, such for example as those employed for basketry, brushes, cordage, furs, hats and paper.

It is a comparatively simple matter to distinguish hair from other fibres and human hair from animal hair, and with experience it is not difficult to differentiate between the hair of different kinds of animals, and occasionally it is possible even to determine the region of the human body from which a particular specimen of hair has been derived.

Sometimes it is useful to know whether certain hair has fallen out naturally or has been torn out forcibly, and this may be determined by an examination of the roots. If the root is small and club-shaped with a rounded extremity and smooth surface, the hair probably has fallen out, whereas if the root possesses an irregular surface and ruptured adherent root-sheaths, the hair has been plucked out. Laves describes a method of staining the sheath and thereby distinguishing it from the cornified part of the hair.[1]

Method of Examination. A rough way of distinguishing between animal and vegetable fibres is to take a few of the fibres to be tested in a pair of forceps, apply a small flame, then withdraw it and allow the fibres to continue burning. Animal fibres burn with some difficulty, curl up, give off the disagreeable smell of burning animal matter and the end of each

[1] W. Laves, *Deutsche Zeitschrift für die Gesamte Gerichtliche Medizin*, **29** (1938), pp. 399–400; also *Journal of Criminal Law and Criminology*, **29** (1938), p. 586

fibre fuses to a rounded nodule. Vegetable fibres, when dry, burn readily, give off a smell resembling that of burning wood and the end remains sharp. As a rule, however, this test cannot be applied, since when found in connexion with a crime, usually there are only a few loose fibres, the recognition of which necessarily must be microscopical as burning would destroy the evidence.

A preliminary examination is made with a lens, the appearance, colour, length, nature of ends (whether blunt, pointed or split) and any other special feature being noted. In the case of all fibres, though more particularly with human hair and fur, the colour may not be natural and the fibre either may have been dyed or bleached. If dye is suspected, the hair should be examined under the ultra-violet rays, which may show a characteristic fluorescence in certain cases. Hair dyes are frequently dilute solutions of compounds of bismuth, lead or silver, though synthetic organic dyes (such as phenylenediamine) or henna (a vegetable dye very common in Egypt) may be used. The principal dyes employed in the fur industry have been recorded by Cox and their distinguishing tests described.[1] If dyeing is suspected a small portion of the hair should be digested in dilute nitric acid and the solution tested for bismuth, lead and silver.

The fibres are examined next microscopically, but before doing this, generally it is necessary to clean them, and in all cases where they have been tested for the presence of dyes they must be washed well in repeated changes of water to free them from all traces of acid. Many fibres may be cleaned by simple immersion in warm water, but if the fibre is hair it must be treated with ether or a mixture of ether and alcohol to remove fatty matter. In either case the fibre is dipped finally in strong alcohol and dried between clean, white blotting paper. For the microscopical examination hairs should be mounted in dilute alcohol or better in Canada balsam and vegetable fibres in Canada balsam, glycerine or glycerine jelly.

Hair that is coloured so strongly as to make microscopic examination difficult or impossible may be decolorized sufficiently to show the structure by treatment with hydrogen peroxide.[2] Roig recommends warm sodium carbonate solution (15 per cent.) for 15 minutes, then hydrogen peroxide (100 vols.) for three hours.[3] Lawrie uses a solution consisting of 5 c.c. hydrogen peroxide (10 vols.), 0·5 c.c. ammonia and 100 c.c. of water.[4]

As an addition to the microscopical examination of hair in the longitudinal plane, cross sections also should be examined, as the shape of the hair and

[1] H. E. Cox, " The Chemical Examination of Furs in Relation to Dermatitis," *Analyst*, **54** (1929), pp. 694–703.
[2] See footnote 4, p. 27.
[3] J. D. Roig, " Technique pour l'examen médico-légal des poils," *Ann. de Méd. lég.*, **12** (1932), pp. 225–7.
[4] L. B. Lawrie, *Textile Microscopy*, p. 99.

the relative proportion of the cortex and medulla sometimes are characteristic. Cross sections are prepared by embedding the hair in paraffin wax and sectioning it with a microtome. The technique is described by Glaister.[1] Frequently it is helpful to stain vegetable fibres before examination, since different fibres give different colours with various reagents, but unfortunately animal fibres cannot be differentiated in this manner.

Many of the colour tests for vegetable fibres given in books are very unsatisfactory and are not recommended. Some of the more useful tests are described in the chapters dealing with the subjects of Paper and String and Rope respectively.[2] Fibres also may be distinguished by their solubilities in various reagents which test is described in connexion with Woven Fabrics.[3] In all colour tests it is important always to employ solutions of the same strength, since variations in the strength of the reagent affect the intensity of the colour produced and, if wet, the fibre must be dried before staining. The colour obtained may vary somewhat with the treatment the fibres have received in any manufacturing process to which they have been subjected, raw fibres frequently giving different results from prepared fibres.

For the microscopical examination of fibres any good microscope may be used, but it should be furnished with objectives giving a magnification of from 300 to 400 diameters. Measurements of the thickness of fibres can be made best with a screw-micrometer eyepiece having two cross hairs, one movable and the other fixed.

It is impossible to convey any reliable impression of the appearance of fibres by means of a written description, and this can be learnt only by direct observation from fibres of known origin, aided to some extent by illustrations such as those given in the books referred to at the end of the chapter. In the case of animal fibres it should not be forgotten that hair from different parts of the body of the same animal may vary considerably, most animals producing two kinds of hair, a long, coarse, stiff hair termed " beard hair," and a shorter, finer, softer and more curly hair called " wool-hair," and these differ not only in appearance but also with respect to the presence or absence of scales and medulla.

Photomicrographs of fibres are useful for attaching to a report or for demonstration purposes in Court.

Woven Fabrics.

The examination of woven fabrics so far as the work concerns the chemico-legal expert generally is for the purpose of discovering a clue that will

[1] J. Glaister, (*a*) " The Medico-Legal Examination of Hairs," *Recent Advances in Forensic Medicine*, S. Smith and J. Glaister, 1931, pp. 87–8 ; (*b*) *A Study of Hairs and Wools*, 1931, pp. 9–10.

[2] See pp. 73, 160. [3] See p. 158.

establish the origin of some material found in connexion with a crime, with sometimes the question of its identity or non-identity with other material of similar appearance. The fabric is examined carefully, measured and described. The examination, which is largely microscopical and chemical, comprises the nature of the fibre, the colour, the method of weaving, the number of threads per inch in each direction of the cloth, the number of twists per inch in a thread and whether right or left, the position and nature of any stains and marks and the nature of any dust or dirt.

Method of Examination. A small piece of the cloth should be unravelled, and, since the warp and weft threads [1] frequently are of different material, these should be examined separately.

If the fabric is of either animal or vegetable fibre alone and not a mixture of the two, a rough way of determining of which it consists is by burning, as already described.[2] In this manner, for example, natural silk may be distinguished from artificial silk. Any further examination is either microscopical or chemical.

The microscopical examination has been dealt with already under the subject of Fibres. As a rule before examination a small portion of the fabric should be boiled with dilute hydrochloric acid (2 per cent.), well washed with water by decantation and dried between filter paper in order to free it from dyes or loading and finishing materials if these are present. It should not be forgotten that the chlorination of wool and the mercerization of cotton may so modify the fibres that the characteristic structure is destroyed.

The chemical method of examination is based on two important facts, one being that various substances give different colours with different fibres and the other that different fibres have different solubilities in various reagents. Both these methods may be used, not only for qualitative testing, but also to determine the proportion in which the several kinds of fibre occur in a mixed fabric.

Colour Reactions. These are described when dealing with the subjects of Paper, and String and Rope respectively.

Solubilities. These are shown in the following table [3]:

Fibre.	Sodium Hydroxide (*a*).		Sulphuric Acid (*a*).		Hydrochloric Acid (*a*).	
	Cold.	Hot.	Cold.	Hot.	Cold.	Hot.
Cotton	insol.	insol.	sol.	sol.	insol.	disintegrated
Linen	insol.	insol.	sol.	sol.	insol.	disintegrated
Silk, mulberry	insol.	sol.	sol.	sol.	sol.	sol.
Silk, Tussah	insol.	sol.	insol.	sol.	insol.	insol.
Wool	insol.	sol.	insol.	sol.	insol.	sol.

(*a*) Strong : duration of experiments 10 minutes.

[*For Notes, see page* 159.

Artificial silk is of so many different kinds that it is impossible to give general reactions ; it may, however, usually be recognized by the brilliant lustre, the wiry appearance of the fibres when magnified and sometimes by the fact that the fibres may be from two to three times the width of those of mulberry silk, though this is not always so. The fibres of Tussah silk are, however, also wider than those of mulberry silk. No difference between genuine and artificial silk is shown when the material is examined under the ultra-violet rays.

The solubility or insolubility in the cold may be tested on a few small fibres under the microscope. The fibres are placed on a microscope slide ; a cover glass put on loosely and a drop of the solution placed in contact with the outer edge of the fibres. This will pass under the cover glass and the reaction may be observed readily.

If it is desired to make the results quantitative, a small piece of fabric is boiled in dilute hydrochloric acid (2 per cent.) to free it from finishing, loading and colouring matters, washed, dried and weighed, then treated with the appropriate solution and again washed, dried and weighed, the difference being the weight of the particular fibre dissolved. The results, however, are only approximate, since many of the fibres shown as insoluble in various reagents are attacked to some extent.

Method of Weaving. This may be ascertained by examining the fabric with a lens. As a rule only broad features are required, any elaborate dissection being unnecessary and it is generally sufficient to ascertain whether the fabric is plain, twilled or figured (has a pattern).

Count. The number of fibres per inch in both the warp and weft directions of the cloth should be counted. In the Gill form of counting apparatus the fabric is placed on the glass top of a small box the inside of which is illuminated by a tiny electric light. This is very useful if there are many examinations to be made and for certain kinds of cloth, but for occasional purposes an ordinary counting glass with a field one inch square will be found satisfactory. The number of twists per inch in a thread and whether these are right (clockwise) or left (counter-clockwise) also should be determined.

Stains and Marks. These should be examined as described under the subject of Clothing.

Dust and Dirt. If present, dust and dirt may be collected in the manner

[1] The warp threads are those parallel to the length of the cloth. The weft threads are those that cross the cloth from edge to edge.

[2] See p. 155.

[3] See also Circular C. 423 by T. M. Pitt ; *U.S. Dept. of Commerce, National Bureau of Standards*, 1939 ; *Microscopic Methods used in Identifying Commercial Fibres.* Also *Analyst*, 64 (1939), pp. 425–430. Also H. L. Davis and H. J. Rynkiewiez, *Industrial and Engineering Chemistry*, 14 (1942), Anal. edition, p. 472. Also *The Journal of The Textile Institute*, June, 1941, pp. 522 *et seq.*

mentioned under the subject of Clothing and examined as described when dealing with Dust and Dirt.

String and Rope

The examination of string or rope found in connexion with a crime often may furnish valuable clues.

The fibres used for making string and rope [1] are very numerous, though the principal are hemp, jute and coir (*Cocos nucifera*), the first, however, not being confined to hemp proper (*Cannabis sativa*),[2] but including such fibres as Sisal hemp (*Agave rigida*), Manila hemp (*Musa textilis*), Sunn hemp (*Crotalaria juncea*), New Zealand flax or hemp (*Phormium tenax*), and many others generally termed hemp. In Egypt ropes are made extensively from date-palm fibre and string from Deccan hemp (*Hibiscus cannabinus*).[3] Cotton is also used for rope-making.

Method of Examination. The nature of the fibre may be ascertained both microscopically and chemically. For the microscopical examination a small piece of the rope is unravelled, boiled with dilute sodium hydroxide solution (2 to 5 per cent.), washed well by decantation, rubbed up in a small porcelain mortar and dried between filter paper. A minute portion is teased out on a slide with microscope needles, mounted in Canada balsam, glycerine or glycerine jelly and examined.

The various fibres may be distinguished chemically by the following reactions [4]:

Fibre.	Phloroglucine (*a*).	Aniline Sulphate (*b*).	Iodine and Sulphuric Acid (*c*).
Coconut (Coir) . . .	red	yellow	yellow
Date-palm	deep red	yellowish	yellow
Flax	nil	nil	blue
Hemp (*Cannabis sativa*) . .	red-violet	yellowish to yellowish-brown	yellow or greenish
Jute	deep red	bright yellow	brownish-yellow

(*a*) and (*b*). See p. 73.

(*c*) The fibre is treated on a microscope slide with a 3 per cent. solution of potassium iodide saturated with iodine. After two minutes the excess of this is removed with filter paper and a drop of a solution consisting of two volumes of water, two volumes of glycerine and three volumes of sulphuric acid is added. This test is not very satisfactory, but sometimes may be useful. The blue coloration with flax is frequently very poor and is not always obtained, while sometimes hemp is coloured blue in parts.

[1] By rope is meant cordage only, iron and steel wire rope being excluded.

[2] Of hemp proper there are several varieties which differ in appearance and quality, the two principal met with in Europe being Italian hemp and Russian hemp.

[3] Also known as Ambari hemp and called *Teel* in Egypt.

[4] See also Circular C. 423 by T. M. Pitt; *U. S. Dept. of Commerce, National Bureau of Standards*, 1939; *Microscopic Methods used in Identifying Commercial Fibres*. Also *Analyst*, 64 (1939), pp. 425–430.

Not only should the nature of the fibre be determined, but that of any sizing material present. The sizing materials generally employed are animal size, tallow, soap and paraffin wax, but sometimes borax, china clay, gum and starch also are used. String and rope too sometimes are tarred and shoe threads waxed or treated with a mixture of beeswax and wood tar (cobbler's wax). Attention also should be directed to the ends to ascertain whether they have been cut or frayed and to any knots or loops and to the manner in which these have been tied.

When examining a rope it is useful to determine (*a*) the " lay," which is the system on which the strands forming the rope are twisted, and which is measured by the angle between the direction of each strand and the direction of the centre line of the rope ; (*b*) the size, which is the circumference in inches ; (*c*) the number of strands ; (*d*) the number of yarns per strand ; and (*e*) the number of fibres per yarn.

Illustrative Cases. 1. On the wax seal impression on an envelope that figured in a case of robbery a few tiny black-looking fibres were found that proved to be dark blue wool and to correspond with the material of the frayed edge of the turned-up sleeve of the coat of one of the persons employed by the firm who had been robbed. This man, however, possibly had helped to seal up the envelope in the first instance.

2. A small quantity of material packed tightly into the nipple of a muzzle-loading pistol with which a woman was shot was found to be wood fibre impregnated with paraffin wax, and therefore almost certainly was part of a match the wood of which had been dipped in the customary way in paraffin wax during manufacture. In all probability the head of a match had been used to fire the pistol in place of a percussion cap.

3. During the search of a house of a person suspected of complicity in several murders, two small bottles containing the dried remains of gum and a brush with dried gum on it were found. These were submitted for examination as it was thought that possibly they had been used for fixing false hair to the face, an informer having stated that this practice was followed. The gum proved to be ordinary gum arabic and not a spirit " gum " as ordinarily employed, and although it might have been used for the purpose suggested, it would not have been satisfactory. Adhering to the brush was a mass of fine fibres that proved to be largely vegetable fibres with a few cat hairs, and although such material might have been used for false hair it did not correspond with that sold locally for the purpose, which consisted of horse hair, goat hair or wool.

4. This concerned the question of whether a piece of material found wrapped round the body of a murdered woman was identical with several other pieces of similar looking material found in the house of one of the

suspected persons. On examination it was found that the various pieces of cloth were cotton, that all the pieces were of the same fineness, that is to say the number of threads to the inch in each direction of the cloth was the same in every case, and that all were the same width between the selvedge edges. These facts, together with the further facts that all the pieces bore a similar coloured stain, that all had been sewn with similar and unusually coarse thread, small portions of which still remained, and that all fitted together, justified the report that the several pieces were of identical material and that at one time they had been sewn together : probably they had formed the loose cover for a couch.

5. The naked body of a man was discovered in a canal, tied up in a sack that was weighted with stones. The sack and stones were submitted to ascertain whether any clues to the murderer could be found.

The sack was of a kind and quality largely used in Egypt for cotton seeds and cereals and similar sacks may be obtained almost anywhere in the country. The sack, however, had been patched in two places and in both instances in a similar manner and with similar material, and on a microscopical examination this material was found to be camel hair and the thread with which it was sewn also was of camel hair. Similar thread also had been used to mend one corner of the sack. From these facts the following conclusions were drawn :

That the sack at one time had belonged to some one who could not obtain readily a new sack and to whom therefore a sack was a thing of value and something to be repaired.

That since similar sacks are employed extensively in Egypt, the ordinary Egyptian would not experience much difficulty in obtaining sacks in good condition and hence would have no need to mend an old sack. Moreover, it is characteristic of the ordinary Egyptian that as a rule he does not mend things, but uses them until they cannot be used any longer and then discards them.

Hence the fact of a mended sack seemed to point away from an ordinary Egyptian and at the same time to some one poorer and less able to obtain sacks, that is by exclusion to a bedouin.

A bedouin was indicated too by the nature of the stones used to weight the sack, which, with two exceptions, were rounded flints, the exceptions being silicified wood, all of which must have come from the desert.[1] It was advised that search should be made for a bedouin and subsequently it was ascertained that a bedouin had committed the crime.

6. In a murder case the rope with which the body was tied was of two kinds, one being native hand-made rope of date-palm fibre and the other

[1] It was of course by no means certain that these stones had been taken directly from the desert, similar stones sometimes being used in Egypt for railway ballast.

a better quality of machine-made rope not of local manufacture. One of the pieces was tied in a manner similar to that used for hobbling animals.

7. In another case a piece of thick rope, employed in connexion with scaffolding, that had given way and so caused an accident, was submitted to ascertain whether it had broken naturally or had been cut intentionally. On examination it was found that the rope was strong and of good quality and, although it showed signs of wear along its whole length, yet apart from the broken portion, it was still fit for use. It had not been cut with a sharp instrument, but manifestly had worn through, probably by friction against a rough surface.

8. As a minor point in connexion with some bombs found by the police in two different places, which were thought might have the same origin, the string tied round the boxes containing them was examined and compared, but was found to be different. In another instance a case containing three bombs was tied with a characteristic blue-coloured string, that had been dyed by means of blue ink. Although this had no special significance in the particular inquiry, it might have been of value in other circumstances.

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CHAPTER IX

FINGER PRINTS, FOOTPRINTS, TRACKS OF VEHICLES AND ERASED NUMBERS ON METAL

Finger Prints

A FULL consideration of finger prints and finger print methods of identification is outside the scope of forensic chemistry and the subject therefore will be dealt with briefly. The chemico-legal expert, however, should know sufficient about the matter to be able to decide whether or not an impression that he may find in the course of his work possesses sufficient clearly defined characteristic detail to make it worth while submitting to the proper authorities. A chemist, too, frequently can advise as to the best way of developing finger prints. Although almost any article touched is liable to retain some impression of the fingers, many impressions, including most of those on rough surfaces, are not of much value for identification purposes.

During the examination of questioned documents finger prints may be noticed. Sometimes these are very manifest and have been made with inky or greasy or otherwise dirty hands. Care should be taken that such marks are not defaced or obliterated and it is a useful precaution to make a photographic enlargement of them, and should the document be an anonymous communication, such as a threatening or libellous letter, this becomes essential. These photographs should be attached to the report, so that they may be dealt with by a specialist. It may happen, too, that papers are sent to the chemist for investigation, that manifestly also should be examined for finger prints, and in such cases special care should be taken in " handling " them, and they should not be touched except with gloved fingers or by means of forceps. Sometimes, however, finger prints that are almost or entirely invisible exist on the paper.

Invisible, but latent, finger prints may be developed and visible finger prints may be intensified in various ways, the choice of which depends usually on the nature of the material on which the prints occur. These methods are, first, by exposure to certain chemical reagents in the form of vapour ; second, by treatment with liquid reagents ; and third, by dusting over with very fine powder, all of which may now briefly be considered.

Vaporized Developers. These are applicable only to finger prints on paper. The principal vapours used are iodine and osmium tetroxide, the latter proposed by Mitchell.[1]

Iodine, although one of the simplest and most satisfactory all-round reagents, suffers from two drawbacks, namely, first, that it is very fugitive,

[1] C. A. Mitchell, " The Detection of Finger Prints on Documents," *The Analyst*, 45 (1920), pp. 122–9.

and second, that its colour renders it difficult to photograph in the ordinary way. The fugitive nature of the developed prints cannot be overcome readily, since most processes of fixing reduce the sharpness of the print.

Heinrich, however, gives a method, based on one by Professor G. Popp, whereby the iodine image is rendered permanent by means of palladium chloride,[1] the details of which are as follows: On withdrawing the paper from the iodine vapour it is held horizontally over a suitably-sized photographic dish and a solution of palladium chloride [2] is poured over it and allowed to remain on for slightly less than one minute, when the solution is poured off into the dish and preserved for future use. The finger print developed by the iodine becomes brown, the shade of colour depending on the extent to which the iodine has been allowed to act. The paper is carefully washed by means of a gentle stream of water from a tap and allowed to dry, but it should not be dried between blotting paper, as this may blur the print.

The colour difficulty may be surmounted by the use of a blue screen. The exposure to iodine vapour should be only of short duration, otherwise the whole paper becomes darkly coloured and the finger prints less distinct.[3]

Wagenaar [4] develops the print with iodine vapour, then makes a contact print on specially prepared paper and finally preserves the print by coating it with a 3 per cent. solution of dammar resin in benzene.

Mitchell applies the osmium tetroxide vapour by exposing the prints to the vapour of a boiling one per cent. solution of this reagent in water.

Liquid Developers. These also are applicable only to finger prints on paper. The most satisfactory consist of coloured solutions,[5] for example, blue, black, or blue-black writing fluid containing little or no solid matter in suspension, such as fountain-pen ink; a similar ink diluted with water, or a solution of coloured dye, generally blue or red in water or alcohol. Mitchell has found that a solution of osmium pyrogallate (2 c.c. ordinary osmic acid as supplied for microscopic work, 2 c.c. water and 0·05 gram pyrogallic acid) gives satisfactory results.[6] All these developers are brushed on to the paper with a camel-hair brush.

Solid Developers. These are employed in the form of very fine powder sprayed or sprinkled on and the excess brushed or blown off, or applied gently with a soft brush in one direction and not brushed to and fro.

[1] E. O. Heinrich, "Development and Fixation of Latent Finger Impressions," *Proceedings of the XVIIth Annual Convention of the California State Division, International Association for Identification*, 1932, pp. 105–6.

[2] Palladium chloride 0·10 gram; tannic acid 0·25 gram; alum, dry, powdered 0·25 gram; hydrochloric acid (10 per cent. solution) 0·50 c.c.; distilled water 100 c.c.

[3] For method of use, see p. 103.

[4] M. Wagenaar, "Method of Rendering Latent Finger-Prints Visible," *Pharm. Weekblad*, 1935, **72**, pp. 1265–1271; *Analyst*, **61** (1936), pp. 131–132.

[5] See pp. 101–102.

[6] C. A. Mitchell, "The Detection of Finger Prints on Documents," *The Analyst*, **45** (1920), pp. 122–9.

Almost any fine powder will give some result, but the best effects are obtained with "grey powder" (mercury and chalk), magnesium carbonate, white lead, red lead and ferric oxide for prints on dark-coloured surfaces and graphite or charcoal powder for light-coloured surfaces. Thomas suggests the use of basic dyes.[1] Brose suggests dusting phosphorescent zinc sulphide on the finger prints and photographing by ultra-violet rays.[2]

All methods of treatment disfigure the paper and should not be employed unless and until it is quite certain that the document will not be required again for other purposes. In every case, however, before any attempt is made to develop finger prints, the document should be photographed first. On one occasion a very faint but just visible finger print was noticed on a document. This was photographed and then was treated in order to intensify it so that a second and better photograph might be obtained, but under treatment the mark disappeared altogether, probably having been washed off mechanically by the solution.

Any finger prints that develop should be photographed and forwarded to the proper authorities for examination: photography is particularly necessary when silver nitrate is employed as the developer, since this gradually darkens on the paper and finally obscures the finger marks. If the finger prints are to be photographed, as is usually the case, the use of a blue solution or a blue powder increases the difficulty of photography, for which reason sometimes it is better to employ a red solution or a red powder.

Mitchell[3] states that the results yielded by the various methods of development of finger prints on paper depend very largely upon the absorptive capacity of the paper, and that in some cases the prints are permanent and can be developed after several years, whereas in other cases the prints show no details after about a week.

In order to prevent finger prints from being smudged or dirtied by handling, they should be fixed, which may be done in the case of charcoal powder by immersion in a solution of equal parts of milk and water[4] or coated with a colourless spirit varnish, such as the fixative sold for use with pastels or a dilute solution of celluloid in acetone or in a mixture of acetone and amyl acetate.

When comparing finger prints developed by powders with those developed by solutions, it should not be forgotten that the former are produced by the powder adhering to the moisture, grease and dirt on those parts of the paper with which the ridges have come in contact, and it is the prints of the ridges therefore that are coloured, the result being a positive. In the

[1] H. A. Thomas, "The Development of Latent Finger-Prints with Dyestuffs," *Analyst*, 62 (1937), pp. 192, 539.
[2] H. L. Brose, "Finger Print Detection," *Analyst*, 59 (1934), pp. 25–7.
[3] C. A. Mitchell, "The Detection of Finger Prints on Documents," *The Analyst*, 45 (1920), p. 124.
[4] H. Battley, *Single Finger Prints*, 1930, p. 74.

second case the part of the paper touched by the ridges, being greasy, repels the solution and therefore takes less colour than the rest of the paper and the result is a negative.

Sometimes it is desired to obtain the finger prints of those who touch certain objects. This is done readily by coating the object in question with a thin film of something that will take and retain the impression of the fingers. For glass a thin layer of gelatine and glycerine, the latter being added to prevent the gelatine drying, will be found satisfactory, while for many opaque objects a very thin film of oil or grease is effective

If the suspected person can be detained and examined, it is sometimes helpful to coat the article likely to be touched with something that will stain the hands, such as aniline colour [1] or a solution of silver nitrate. This latter may be prevented from drying by adding a deliquescent material like calcium nitrate. Anthracene powder also has been suggested and may be detected by the fluorescence produced when exposed to ultra-violet rays.

In connexion with this subject it should not be forgotten that finger prints may be forged [2 3 4] or taken after death.

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FOOTPRINTS

The methods of taking and comparing footprints are largely matters of police routine outside the domain of forensic chemistry, but a few points respecting the materials employed may be mentioned.

The two principal materials suggested for taking casts of footprints are (*a*) plaster of paris and (*b*) a mixture of paraffin wax (one part) and ordinary resin [5] (two parts), the second being recommended by a Home Office Circular (1892) to the Police and its use being advocated by the Assistant Chief Constable of Birmingham.[6]

If plaster of paris is used, it should be of the very best quality that has not deteriorated by having been kept in a damp place ; it is prepared for

[1] W. M. Else and J. M. Garrow, *The Detection of Crime*, pp. 45–9.
[2] H. Cummins, " Counterfeit Finger-Prints," *Journal of Criminal Law and Criminology*, 25 (1934), pp. 666–71.
[3] C. D. Lee, " Finger-Prints can be Forged," *Journal of Criminal Law and Criminology*, 25 (1934), pp. 671–4.
[4] A. W. W. Harper, " Fingerprint ' Forgery '—Transferred Latent Fingerprints," *Journal of Criminal Law and Criminology*, 28 (1937), pp. 573–580.
[5] Rosin, colophony.
[6] Cecil C. H. Moriarty, " Taking of Casts of Footprints," *The Police Journal*, 5 (1932), pp. 229–32.

use as follows: Take as much water in a small bucket or large basin as will give the required quantity of plaster, about a pint of water for each footprint, and into this sprinkle, rapidly and uniformly, with the dry hand, the plaster in fine powder. At first the plaster sinks and the sprinkling is continued until, instead of sinking, it stands in the centre just above the surface of the water. This gradual saturation of the plaster from below expels the air without causing bubbles, which should be avoided. Mix well with the hand or with a piece of wood in such a manner that the hand or wood is not brought to the surface during the operation, otherwise air is carried in, causing bubbles. Finally skim off any bubbles or scum that may have formed. The plaster, which should be about the consistency of cream, must be used quickly and should be poured on the footprint (at first very gently) from a small receptacle such as a large spoon or small cup. The cast, when thoroughly dry, may be hardened by repeated treatment with a dilute solution of celluloid (1 per cent.) in acetone or in mixed acetone and amyl acetate, or by means of very hot paraffin wax applied either by immersing the cast in the melted wax or with a brush, until the plaster will not absorb any more. Excess wax on the surface may be removed by warming.

The setting of plaster of paris may be hastened or retarded by dissolving certain substances in the water used for mixing. Generally, however, any hastening of the set is unnecessary, as the plaster will set quite rapidly enough for the purpose required and occasionally even too rapidly. When the latter occurs the set may be retarded by dissolving a little gum or glue in the water, both of which also harden the plaster and give it a better surface.

The wax-and-resin mixture, which is made easily, should be kept ready for use, so as merely to require melting on the scene where the footprints occur, the best method of doing this being in a kettle, on account of the spout and the consequent ease of pouring and also because of the lid, which is a measure of safety. Special precautions should be taken in filling the kettle to avoid smearing any of the substance on the outside, where it would take fire and imperil the rest, and also not to heat the material more then a few degrees above the melting point, otherwise the risks of it taking fire become considerable. The mixture should be poured into the footprints very gently at first from a small receptacle and only later directly from the kettle.

Martin recommends the use of modelling wax.[1]

A method of removing footprints bodily from certain surfaces such as linoleum, stone, wood and concrete has been published,[2] and is as follows: A mask (frame) of cardboard or stout paper is cut out and placed over the print and is held flat on the surface while a solution of cellulose acetate (8 per cent. of cellulose acetate dissolved in acetone) is poured both over

[1] F. W. Martin, *The Police Journal*, 9 (1936), pp. 450–452.

[2] F. G. Tryhorn, *The Police Journal*, 8 (1935), p. 25.

the print and over the inner edges of the mask to a thickness of about one-sixteenth of an inch. When dry, a tough transparent film is left, which may be removed by gently lifting the corners of the mask, the film bringing away with it every trace of the footprint. Before the film has time to shrink, which it does after a time, a positive photographic print should be made from it on bromide paper, from which measurements may be taken.

Illustrative Cases. 1. The value of making casts of footprints was well illustrated during the Arlosoroff murder trial in Palestine in 1934. In this case certain footprints that the prosecution stated were those of the murderer were proved by the defence to have been made by mounted policemen (who at the time were on foot) while searching for the murderer. The proof was that plaster casts of the footprints in question reproduced the impressions that had been made in the sand by the spur chains worn by the police.

2. In the case of a very serious robbery investigated by the Cairo City Police, there was an iron door leading to a basement room, where much valuable material was stored to protect it from air raids. This door had been forced open by kicking it. The floor of the passage leading to the door was very dusty, and well-marked footprints were left on the door, and on these footprints the letters D and O were plainly visible. When the shoes of one of the suspects were examined, it was found that they had been soled with pieces of old Dunlop motor tyres on which were the same letters. Photographs made by the Police Finger Print Department of the marks on the door and of the shoe soles proved the identity of the two lots of marks, and the man was convicted.

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TRACKS OF VEHICLES

The identification of vehicle, especially motor vehicle, tracks, like that of finger prints and footprints, is a matter for the police, but reference may be made to three illustrated articles on the subject.

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Erased Numbers on Metal

Numbers are frequently removed from stolen motor cars, motor cycles, firearms and other metal objects in order to prevent them from being identified, or sometimes numbers, or other marks, are altered. If either is suspected, the surface of the metal should be cleaned well from grease or paint and examined carefully for evidence of filing or grinding.

The cleaning should be done by means of a solvent, such as petrol, for oil or grease, and turpentine for paint, or the latter may be burned off with a painter's or plumber's blow-lamp. Scraping should be avoided, as this may make the subsequent development more difficult.

When a number is punched into metal, the portion of the metal below the number is hardened, and its molecular structure possibly changed, and even when the number has been removed, the hardness of the metal immediately below persists. This latent number may be developed by grinding down the surface of the metal with emery, highly polishing it and then etching it, when the hardened portions below the number stand up in very slight relief and may be seen when viewed in a strong side light.

To etch the metal, the surface is first cleaned from grease with petrol and then immersed in a solution, the nature of which varies with the kind of metal, but which is similar to the solutions used in the microscopical examination of metals.[1] [2]

Davis recommends the use of heat, applied by means of an acetylene torch, for developing latent numbers on iron, though not on steel, for which he says heat ordinarily is unsatisfactory.

In this connexion the so-called Japanese "magic" mirror may be mentioned. This is a small metal hand-mirror with a highly polished face and a richly ornamented back, which is made from a copper-tin alloy, either ordinary bronze or speculum metal. The design is put on the back not by etching, but by hammering with a chisel, when the metal under the design becomes hardened. The design is made deep enough to show slightly through at the front. This is rubbed down and well polished, but the design, although ordinarily invisible, still persists, and, if a beam of light is reflected from the *face*, and the reflection received on a suitable surface, the design which apparently has been removed shows plainly.

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[1] G. W. Pirk. See Bibliography.

[2] P. Law. See Bibliography.

CHAPTER X

FIRES AND INSURANCE FRAUDS

FIRES ought to provide a fruitful field of work for the chemico-legal expert, but it is one in which his services are utilized too little, with the result that the origin of many fires is never ascertained even when they are the work of an incendiary, and often they are attributed to spontaneous ignition without any evidence, and sometimes even when this is chemically impossible.

Spontaneous ignition, although it does occur (for example with coal, hay, certain oils and grease, and phosphorus), is compartively rare, and should never be accepted as the cause of a fire unless the circumstances have been investigated by a chemist.

No general rules can be formulated concerning the procedure to be adopted in investigating the origin of a fire, but each case must be studied and dealt with as a separate and special problem. The principal points requiring attention are, first, that a general examination of the whole of the damaged premises should be made; second, that a more detailed examination of the spot where the fire originated, or is supposed to have originated, is necessary; and, third, that an explanation of the possible origin of the fire and a description of its progress should be obtained from the officer in charge of the fire brigade, from any policeman or watchman on duty, and from the occupier of the premises; and those who first saw the outbreak. In all such investigations it should never be forgotten that a competent fireman is an experienced expert, and his opinion should be asked for specially and considered carefully. In many cases it is necessary to take samples of materials stored on the premises for analysis if there is anything that is likely to have caused the fire. Thus inflammable liquids or explosive materials should always be sampled if any portion is left. Oils, particularly fuel oil, also should be sampled. Such obvious things as paraffin oil (kerosene) or oily rags, if present, will probably have been discovered by the firemen, but they should be looked for, especially if the fire has been extinguished at an early stage. Even in cases where the premises have been gutted completely, and where it is thought that little that is helpful will be found, the expert should not neglect to make a careful inspection.

Among the points that call for special attention are the following:

(*a*) The gas meter, to ascertain whether the gas had been turned off.

(*b*) Gas fittings, to see whether any of the taps had been left open.

(*c*) Oil stoves and lamps and whether the taps are open or closed.

(*d*) Electric fittings, apparatus and wiring, particularly electric irons, the condition of which may show whether the fire has originated with them.

(*e*) The presence and position of gas jets, lamps, fires, stoves and furnaces, since vapours from volatile liquids may reach a light or fire from a considerable distance.

(*f*) The presence of inflammable liquids, explosives, strong mineral acids and of anything liable to spontaneous ignition.

The fact that petrol vapour is heavier than air and will travel comparatively long distances along the ground generally is unknown, as is also the fact that a small proportion (from 2½ to 5 per cent.) of petrol or other inflammable vapour in the atmosphere will produce explosive mixtures, a larger proportion being inflammable but not explosive.

If there is reason to suspect, on account of the smell, that certain material found at the scene of the fire has been saturated with petroleum spirit (benzine, petrol), paraffin oil (kerosene), alcohol, or other inflammable liquid, this material, or part of it, should, if possible, be put at once into a clean, dry, wide-mouthed glass bottle or into a clean tin box and submitted without delay to the chemist, who will be able to separate any liquid present and to prove its nature by the appropriate tests. Frequently this is not done, reliance being placed upon the recognition of the substance by smell alone. The sense of smell, however, is liable to error, or it may be disputed, and it is far more satisfactory to have the evidence of one who has tested a substance and can possibly even produce a specimen of it in Court.

To separate inflammable liquids of low boiling point the material should be placed in a small glass vessel connected with a small condenser and receiver (a small test tube often being a suitable receiver) and heated on the water bath. For liquids of higher boiling points than those mentioned an oil bath should be used and on no account should the heating be carried out by the application of a flame directly to the container, as this would char any fabric or shavings producing bodies that would contaminate the distillate.

Many fires are of electrical origin, one very common cause of fires in certain industries being the generation of static (frictional) electricity upon the moving parts of machinery or upon moving materials in the presence of easily ignitable substances, such as organic dust (for example, coal dust, cotton dust or flour dust) or inflammable vapours (for example, petrol vapour). Thus the ginning of cotton [1] the cleaning of fabrics with petrol and the passing of petrol in quantity from one receptacle to another may all give rise to fires. Fires may also result from a short-circuit due to some defect in the electrical installation, or occasionally from an electrically-heated iron being left in position after use. An electric iron left in circuit will in course of time burn anything inflammable with which it is in contact, and a very large fire in Cairo originated in this manner. An

[1] See pp. 173–174.

iron filled with burning charcoal of the kind used in Egypt by native tailors is also sufficient to produce a fire. These causes, however, are not primarily chemical, and only concern the chemical expert indirectly, and he should remember that he is not called in to replace the head of the fire brigade but to aid him in chemical matters. When an electric origin for a fire is suspected, an electrical expert should be consulted.

Quicklime. The sudden slaking of a large quantity of quicklime gives rise to a considerable amount of heat, which may be sufficient to ignite combustible material, such as wood, in contact with the lime.[1] Thus, in 1894 seventeen fires that occurred in London were reported to have been due to the slaking of quicklime in contact with combustible bodies, in eight cases the slaking having been caused by rain.[2]

Cotton. Cotton fires are of frequent occurrence in a cotton-growing country like Egypt, and the loss sustained is sometimes considerable. A brief reference to these fires may be of interest.

For the purpose of fire risks cotton may be divided into two kinds, namely seed cotton, that is to say cotton in the state in which it is gathered and still containing the seeds, and lint or ginned cotton, which is the cotton after the seeds have been separated by the process of ginning.

Seed cotton is comparatively difficult to burn, and although it can readily be ignited, it merely flashes over and the fire soon goes out. This is generally recognized, and unginned cotton is not regarded as a hazardous risk and is not usually insured and very few fires take place, although it is exposed to much the same risks during transport and storage as ginned cotton. It is stated, however, that seed cotton from Upper Egypt, being drier than that from Lower Egypt, burns more readiiy. During the American civil war when orders were issued to burn cotton, this proved to be a difficult matter, and the only way that was found satisfactory was to fire the building in which the cotton was stored, and even then some of the cotton frequently escaped destruction.

During ginning a vary large number of fires occur, as many as one hundred a day having been recorded in Egypt in a single ginnery.[3] These fires, however, are provided against and are promptly extinguished, and as a rule cause very little direct damage: they are due to three principal causes, namely (*a*) occasionally to matches accidentally dropped at some previous stage into the cotton by workmen, who often carry a few loose ones tucked into their headdress; (*b*) possibly sometimes to small stones, sand, grit or

[1] O. Wawrziniok, "Fire Risks in Slaking Lime," *Tonind. Ztg.*, 38, 1423–4 (1914); *Chemical Abstracts* 9 (1915), p. 240.

[2] H. J. Phillips, *The Handling of Dangerous Goods*, 1896, p. 262.

[3] In Texas an average of five fires to each ginning factory during one season is stated to be a conservative estimate. (H. E. Roethe, *U.S. Dept. of Agric. Circular No.* 76, 1929.)

plant stalks, all of which not infrequently find their way into the cotton before ginning. During the process of ginning a considerable amount of heat is generated by the friction of the cotton fibre and seeds against the steel knives and the leather roller of the gin and these become so hot that they cannot be touched with comfort, a temperature of 38° C. (100° F.) having been noticed with a hand gin and a temperature of 45° C. (113° F.) with a full-sized gin. When to the usual friction there is added that caused by foreign bodies, the temperature reached may be considerably more than that mentioned and may even be sufficient to fire the cotton dust always present. Stones and grit, too, by contact with the steel knives, one of which is moving rapidly (800 to 900 movements a minute), may generate sparks that might fire the cotton ; (*c*) to static (frictional) electricity, that is electricity generated by friction and causing sparks. This undoubtedly is the most frequent cause of ginnery fires. In the dry climate of Egypt a charge of static electricity collects on the metallic parts of the gin and when the intensity of the charge is sufficiently strong a spark passes to an adjoining part of the gin that has a charge of lower intensity. Such sparks in the presence of cotton dust will cause a fire and there is little doubt that the majority of ginnery fires are produced in this manner. The conditions most favourable to such fires are low relative humidity of the air and cotton that is dry and dirty. Fires due to static electricity may readily be avoided by connecting the metal parts of the gin by means of insulated copper wire to one another and to the ground, as earthing prevents the accumulation of sufficient static pressure to cause sparking.

After ginning, the cotton is pressed by means of hydraulic presses into bales that are sent to Alexandria, this being the principal Egyptian port from which cotton leaves the country. At Alexandria the bales are opened and the cotton is sorted and afterwards re-pressed by steam presses into more compact bales for export. Very few fires originate in these export bales, since they are as hard as wood, having a density of about 0·6, and do not readily ignite.

All the serious fires take place in the hydraulic pressed bales from the ginneries, either during transport to or storage at Alexandria. These bales are not very tightly packed, their density being only between 0·2 and 0·3, and after much handling they become very loose, particularly at the corners. Such bales are ignited readily and ginned cotton when once alight is very difficult to extinguish and may smoulder until the whole is consumed.

When a fire originates on the outside of a bale it is manifestly due to extraneous causes, which may be the lighted end of a cigarette carelessly thrown away or other negligence, sparks or red-hot cinders from a locomotive, or incendiarism. When, however, the fire originates inside a bale, as undoubtedly is sometimes the case, it is due to particles of smouldering

cotton from an incompletely extinguished fire having been included in the bale at the ginnery.

The time required for the cotton to pass from the gin to the bale is so short and the watering before pressing so slight and so partial that there is nothing inherently impossible in the assumption that a particle of smouldering cotton occasionally escapes extinction. Ginned cotton, too, smoulders in such a quiet and unostentatious a manner that it is by no means an easy matter, short of flooding the cotton with water (which would have to be dried out again, and which is an impracticable measure and would discolour the cotton) to make sure that a fire has been absolutely extinguished, a fact that is fully recognized by firemen and all who deal with cotton salvaged from a fire. How long cotton may smoulder inside a bale before the fire manifests itself outside the bale is uncertain and estimates obtained from those in the cotton trade have varied from three to eight days. Cotton that has been packed at a ginnery soon after a fire is always potentially dangerous.

It is sometimes suggested that since cotton naturally contains a little oil and since additional oil may gain access from crushed seeds, spontaneous ignition therefore is possible. Although there is no doubt that under certain conditions cotton impregnated with cotton seed oil will take fire spontaneously, there is no evidence that cotton fires in Egypt are ever due to this cause. The amount of oil present in the cotton naturally is only a trace, the amount that gets into the cotton in any one area from crushed seeds is very small and is probably present in every bale, and there are so many other causes that can be proved to operate that it is unnecessary to invoke the aid of spontaneous ignition in order to account for the fires that occur.

In connexion with some experiments on the spontaneous inflammability of cotton, I determined the temperature of ignition of various kinds of matches and found that ordinary matches ignited at temperatures varying from 40° C. to 85° C. (104° F. to 185° F.) and safety matches from 120° C. to 175° C. (248° F. to 347° F.). In two experiments made in Texas, one where 500 matches were introduced into the cotton and the other where 85 matches were used, two small fires occurred in each case.[1]

Sodium Nitrate. Sodium nitrate is employed in considerable quantity as a fertilizer and fires occur sometimes during the unloading of the steamers and during the transit of this material by rail or river. This compound is not inflammable, but fabrics and other organic material impregnated with it readily take fire and when this happens the nitrate aids the combustion by furnishing oxygen. When bags containing sodium nitrate are exposed to wet, some of the nitrate dissolves and saturates the bags and these when dry again are in the condition of touch paper or tinder and take fire readily and can be ignited by a spark. In a country like Egypt where cigarette

[1] H. E. Roethe, *U.S. Dept. of Agric. Circular No.* 76, 1929.

smoking is very prevalent and where men smoke during their work, the immediate cause of such fires is almost always a lighted cigarette end carelessly thrown away, except in those cases where the fire occurs on the railway, when it may be due to sparks or red-hot cinders from a locomotive.

Potassium Chlorate. This is largely used in the manufacture of matches, fireworks and explosives. By itself it is neither combustible nor explosive, but it is a strong supporter of combustion because it furnishes oxygen. When mixed with certain substances particularly sugar, sulphur, sawdust, oil, grease, greasy rags, or organic matter of a combustible nature, the mixture is extremely dangerous and may be ignited or exploded readily by percussion, friction, or a spark. Serious accidents have occurred from carrying lozenges of potassium chlorate (chlorate of potash) in the same pocket as matches or matchboxes having on them an igniting composition.

Insurance Frauds. Fraudulent claims are sometimes made in respect to goods that have been largely or wholly destroyed by fire, or damaged either by a fire or by the water used to extinguish it, such claims being incorrect with regard to the extent of the loss or in respect to the original quality of the goods, and the chemist is often able to prove that the injury is not of the nature or extent stated or that the goods were not of the quality claimed.

In this connexion insurance claims of a similar nature to those just referred to, but unconnected with fires, may be mentioned. Thus when goods that have been forwarded from one place to another by sea, canal, rail or other form of transport, arrive at their destination in a damaged condition, insurance claims are sometimes made, often in good faith, the damage being generally attributed to the action of sea water or rain water during transit, though it may be due to the goods having been of poor quality originally and having undergone natural deterioration. Instances of this kind that have been investigated include beer that had been defective originally ; tinned fruit, where the corrosion of the tins complained of had been caused by the fruit juice and not by outside agencies as alleged, and soda crystals that had lost their water of crystallization in the hot dry climate of Egypt.

It is sometimes necessary to distinguish between the effects of rain water and those of sea water and usually this is a very simple matter, though in one instance it could not be done as the goods consisted of salted hams. In several cases it has been possible to prove that goods stated to have been injured by sea water had not been in contact with salt water, while in other cases alleged damage by sea water has been confirmed.[1]

Illustrative Cases. 1. A portion of a sack that was very much burned but which still smelled strongly of paraffin oil (kerosene) was discovered,

[1] See also W. M. Seaber, " Testing for Sea Water Damage," *Analyst*, 61 (1936), pp. 14-22.

and when this was examined carefully some wheat husks and particles of wheat flour were found inside the bottom seam and bottom corners and a small amount of whitish material caked in patches on the outside was found also to consist of wheat flour. These facts enabled the police to fix the crime upon a certain baker.

2. A sleeping man who had wrapped his head up in the usual Egyptian fashion woke feeling very hot and discovered that while asleep he had been covered with a sack saturated with paraffin oil that had been lighted. As it is not an easy matter to light paraffin oil with a match, the greater part of a box of matches had been used up in the attempt, the burned remains of which were found scattered about. The sack had on it an illegible inscription which it was thought might provide a clue, but although the sack was cleaned and the inscription deciphered, the author of the crime was never traced.

3. One serious fire was caused by the leakage of fuel oil from a small tank placed above a boiler (which was oil fired) into the furnace. The tank was an old one made of thin sheet iron and had a hole in the side that had been repaired. The patch, however, was not rivetted on, as it should have been, but soldered, and had come off, or partly off, allowing the oil to run down the front of the boiler into the furnace, where it took fire, this spreading to the oil in the tank and thence to the wooden rafters in the roof. The small tank was filled by a hand pump from a large covered masonry tank below the ground and adjoining the boiler. The flash point of the oil was satisfactory, being 238° F., and the oil in the large tank did not take fire. The oil was very thick and was heated in the small tank by means of a steam coil in order to render it sufficiently liquid to flow readily. There was manifestly either ignorance or negligence on the part of the owner in using an old tank that had been badly repaired and in placing this tank in such a position that in case of a leak the oil would run into the furnace.

4. A serious fire on a barge carrying bales of ginned cotton was attributed to the explosion of a small Primus stove burning paraffin oil (kerosene), but this stove, although manifestly it had been exposed to considerable heat, was in excellent condition and there were no signs of rupture or distortion, the only damage done being that the legs and pump, originally attached by solder, had become detached owing to the solder melting and that there was a small *inward* dent at the bottom with a tiny hole in the hollow. One " expert " had scraped the edges of this hole with the point of his penknife, thus making the nature of the edges, which when seen were smooth, of no value as evidence and the cause of the dent and hole was not determined. From the position of the fire when first seen, from the rapidity with which it had spread and from the condition of the barge and especially of the cabin where the Primus stove was found, it was manifest that the stove

had no connexion with the fire, but that this had been burning some time before it was detected and that it was almost certainly due to smouldering cotton having been included in one of the bales at the ginnery.

5. Three cases proved to be examples of spontaneous ignition, one being caused by freshly made charcoal in small pieces, another by locally made rat poison that contained a large proportion of yellow phosphorus, that had taken fire spontaneously and had ignited some material with which it was in contact, and the third by the action of nitric acid. A quantity of this acid in a corked bottle was packed in wood shavings, and adjacent to it in the same box was another bottle containing a mixture of bitumen and turpentine that probably was broken in transit. Probably, too, at some time the box was placed upside down, and if so the acid would gradually have found its way through the cork, and assuming the bottle containing the turpentine mixture had been broken, the acid coming in contact with the turpentine would have acted upon it vigorously, and would have developed sufficient heat to have caused the fire.

6. One unusual fire, in which a person was badly burned, was due to the combustion of chromium trioxide crystals during the emptying of a drum. The fire was almost certainly started by a lighted cigarette, or cigarette end dropped accidentally into the drum.

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CHAPTER XI

FIREARMS, CARTRIDGES AND PROJECTILES

In case of wounds or death by shooting, a considerable amount of valuable evidence may be obtained from firearms, cartridges, projectiles, fired cartridge cases and wads found in connexion with the accident or crime.

Firearms

Firearms comprise military and sporting rifles, shotguns, revolvers and self-loading [1] and other pistols, which may be divided into two types, namely smooth-bore weapons and rifled arms.

Smooth-bore Weapons. These, as the name indicates, are weapons of which the bore, which is the hole in the barrel, is smooth. The principal example of such weapons is the ordinary shotgun, which is used with a charge of small shot (pellets) for shooting small game. Another example is the gun which fires cartridges containing lead slugs, such as are supplied to certain Government watchmen in Egypt and doubtless elsewhere.

Rifled Arms. These are weapons of which the bore is rifled [2] and they comprise military rifles, sporting rifles, revolvers, self-loading, automatic and other pistols.

From the point of view of criminal investigation, the important features of firearms are (*a*) the nature of any fouling left in the barrel; (*b*) the condition of the weapon and its calibre; (*c*) the rifling of rifled arms; (*d*) any irregularities or imperfections in the interior of the barrel, particularly near the muzzle end; (*e*) the shape of the end (nose) of the striker (firing pin, hammer), with any irregularities on it caused either during manufacture or due to subsequent accident or wear; (*f*) any file marks, machine marks or other marks on the face of the breech shield (breech block) or in rifles the bolt head, against which the base of the cartridge is forced by the gas pressure developed on firing; (*g*) the extractor hook (claw), if any, and (*h*) the ejector, if any, all of which features may now separately be considered.

Fouling. Apart from a small amount of metallic fouling caused by particles of the projectile being scraped off and remaining in the barrel, the material left in the firearm after it has been discharged consists of gaseous

[1] The term " automatic " is correctly applied only to a firearm that is fully automatic, namely one that is reloaded, recocked *and discharged* automatically, that is one which will continue to fire as long as the trigger is pressed, whereas what is popularly known as an " automatic pistol " is automatic only to the extent of self-loading and self-cocking and it requires fresh trigger pressure for each shot fired. Such a weapon, therefore is better called a " self-loading " pistol, which will be done in the present book.

[2] See pp. 191–194.

and solid matter derived from the powder and cap composition. The nature of the fouling, therefore, depends to some extent upon the kind of projectile used, whether for example it is naked lead or nickel-coated, but it depends more particularly upon the kind of powder employed. Since metallic fouling has very little direct significance in criminal investigation, it will not be dealt with further in connexion with fouling, but only in so far as it may affect either the barrel or the bullet.[1]

Fouling has been placed first among the features requiring investigation, not because it is the most important, but because, if it is to be considered at all, this should be done as soon after the firing as possible, since among the components are some that are evanescent or unstable, and it becomes essential, therefore, that these should be tested for before they have had time to disappear or before any chemical changes have taken place in them. If the fouling is to be examined, therefore, it is necessary that the weapon should be submitted to the expert at as early a stage in the inquiry as possible and that nothing (neither a finger nor a handkerchief, for example) should be introduced into the barrel to ascertain whether it is dirty or not, otherwise evidence of value may be lost or even misleading evidence may be produced. If the weapon cannot be handed to the expert, but has to be forwarded, it should be wrapped carefully in clean paper, tied and sealed and sent by special messenger.

On receipt of the weapon, the expert immediately should determine the nature and extent of the fouling before any other examination is made, as all other points, no matter how important, can be considered equally well at a later stage.

The question of whether the fouling should be examined chemically or not is one that can be decided only in connexion with the other aspects of the case, for example, if the weapon is a rifle or a self-loading pistol, the propellent is almost certain to have been smokeless (nitro) powder, in which case chemical testing of the fouling is often unnecessary, or at least of secondary importance, whereas in the case of shotguns and revolvers, the question of whether black powder or smokeless powder has been used may be of primary importance. In the case of smokeless powder, too, the residue left in the barrel does not indicate when the weapon has been fired, whereas with black powder this point sometimes may be determined within certain limits and may constitute valuable evidence. The chemical examination of the fouling does not destroy any strongly adherent rust in the barrel, that might be of importance from other aspects, nor does it result in further rusting, which might introduce misleading indications, if the water employed for washing out the barrel is hot and if the barrel is oiled very slightly afterwards.

[1] See p. 196.

Powder. Powder for firearms is essentially of two kinds, namely, black powder (ordinary gunpowder) and smokeless (nitro) powder.[1] [2] Military rifle ammunition is loaded with smokeless powder; sporting rifle ammunition may contain either black powder or smokeless powder; self-loading pistol ammunition always contains smokeless powder; modern revolver ammunition generally contains smokeless powder, but may contain black powder; shotgun ammunition may be loaded either with black powder or with smokeless powder.

Black Powder. This consists essentially of an intimate mixture of charcoal (about 15 per cent.), potassium or sodium nitrate (about 75 per cent.) and sulphur (about 10 per cent.). Owing to a temporary shortage of potassium nitrate during the war of 1914-18 the use of sodium nitrate was allowed in England for ordinary gunpowder, and H.M. Inspectors of Explosives have adopted permanently the view that "gunpowder ordinarily so called" may be made with either potassium or sodium nitrate.[3] Although every effort is made by the manufacturer to obtain the required ingredients of as uniform and pure a quality as possible, slight differences of composition cannot be avoided, and although all black powder for firearms, whatever its origin, approximates closely to the same composition, the proportion of the various ingredients is not always absolutely identical. It follows, therefore, that the products of combustion must show variations corresponding to the differences in composition of the original powder, but these variations are so slight as to be negligible from a forensic point of view.

The principal final products formed when black powder is used in a firearm are as follows[4]:

Gases: Carbon dioxide; Carbon monoxide; Hydrogen; Methane; Nitrogen; Sulphuretted hydrogen.

Solids: Potassium carbonate; Potassium sulphate; Potassium sulphide; Potassium thiocyanate.

In addition to the products of combustion mentioned there is always a

[1] Sometimes a mixture of black powder and smokeless powder, termed "semi-smokeless powder," is used.

[2] Smokeless powder is coated sometimes with graphite and is then dark-grey or black on the surface.

[3] *Annual Report of H. M. Inspectors of Explosives*, 1914.

[4] The priming of the cap, which may vary in composition, affects the results slightly. The priming of the British military rifle cap consists of fulminate of mercury, chlorate of potassium, sulphide of antimony, sulphur and black powder.

little water vapour; a little of the original charcoal which is left unconsumed, though the greater part of it escapes as smoke and a little sulphur which is also left, and which generally combines with the potassium monosulphide produced to form polysulphides. It is stated too that a little potassium nitrate is left, but although I have tested frequently for nitrate, the results invariably have been negative.[1] A trace of nitrate, however, is found generally after the sulphide has disappeared. Potassium thiosulphate also is stated to be formed, and always was found when tested for, but probably it is not an original product but a secondary product resulting from the oxidation of potassium sulphide. The work undertaken by me was not a research into the exact composition of the compounds produced by the combustion of gunpowder nor into their methods of formation, but merely an inquiry into what compounds, for which there are good positive tests, that may be applied away from the laboratory if necessary, are present in the barrel of a firearm at various intervals after the firearm has been discharged.

From the nature of the residue left in the barrel attempts have been made to fix the time that has elapsed since discharge took place. Thus sometimes very precise statements concerning this matter are made with reference to black powder. Such statements, however, are usually both incomplete and wrong, and hence may be misleading, since persons having little knowledge of firearms, and less of chemistry, sometimes are apt to accept definite statements found in a well known book, as though they had been proved conclusively and admitted generally, and were true for all time and under all conditions.

A number of tests were made by me in connexion with this matter, and under the conditions of the experiments the results were as follows [2]:

A characteristic smell that decreased in intensity with lapse of time was present immediately after firing, but even after several weeks some slight smell remained. The greatest caution is required in respect to the identification by odour alone of the components of this smell, and although it was proved that sulphuretted hydrogen was present at first, I was never able positively to identify this compound by the smell, but only by chemical tests.

Sulphuretted hydrogen was present in the gaseous state and was detected by means of lead test paper, but it quickly disappeared, the time taken for

[1] The tests were made after firing cartridges of good quality, when apparently the combustion of the powder was complete. With badly made cartridges or with a muzzle-loading gun and an excess of powder the combustion may not be complete, and in such cases a little of the nitrate of the powder may be left unconsumed.

[2] The experiments with very few exceptions were made with a 12-bore double-barrelled shotgun, using either Eley cartridges and No. 10 shot or Belgian cartridges and No. 6½ shot. About 100 experiments were made altogether. The gun was cleaned well each time before use.

the complete disappearance depending largely upon whether the breech had been opened and whether the fired cartridge case had been removed.

Solid matter was deposited in the barrel. As seen at the muzzle end, where alone it could be examined critically, this deposit was generally black and frequently a very intense black but sometimes dark grey, and a clean white fabric introduced into the barrel became soiled. The colour of this deposit changed gradually with lapse of time, the black disappearing and light-coloured particles being formed, the whole deposit eventually becoming light grey or sometimes even practically white. After a further period, however, brown streaks and patches appeared and the deposit became partly brown. The black was not entirely, nor even principally, carbon, but consisted of sulphide of iron with a little carbon and sometimes a little sulphide of lead. The light-coloured particles contained sulphate, carbonate and compounds of potassium, iron and sometimes lead. The brown coloration was due to oxide of iron (rust). The changes mentioned manifestly were due largely to the oxidation of ferrous sulphide to ferrous sulphate with the subsequent formation of ferric oxide.

The solution obtained by washing out the barrel with water immediately after firing contained black particles in suspension, was of a greenish or yellowish colour, smelled of sulphuretted hydrogen, was alkaline and contained sulphide, sulphate, no nitrite or nitrate, but sometimes a trace of ferrous iron. When various intervals of time, gradually increasing in length, were allowed to elapse before the barrel was washed out, the suspended matter, which at first was black, finally became grey or brown, while the solution gradually lost its green or yellow colour and became colourless or brown. The sulphide disappeared, but the alkalinity, sulphate and iron remained, and a little nitrite developed. The suspended matter at first contained iron in the ferrous condition, but later part of the iron was in the ferric state.

The time limits found during which the compounds originally present persisted, and after which others were formed, were as follows :

Colour. As already explained, the colour of the deposit in the barrel, even immediately after a firearm had been discharged, was not always the same, being much blacker on some occasions than on others, and even the two barrels of the same gun fired at the same time with cartridges from the same box may differ. The light-coloured particles generally began to form very soon, even after one day, but rusting as a rule did not commence for several days. The results, however, were not always the same, and no definite rule can be laid down.

Sulphuretted Hydrogen in the Gaseous State. When the breech was kept closed this compound was found to persist for periods varying between two and three hours, but when the breech was opened and the fired cartridge

case removed it sometimes disappeared entirely in less than one minute and never lasted for more than five minutes.

SULPHIDE. The greater part of this disappeared in about four to five hours, but frequently a trace remained for some time longer, the longest period during which sulphide persisted in the experiments made being ten hours.

SULPHATE. This was always present from the first, and it did not appear only at a later stage as several writers would appear to imply : the amount, however, increased, additional sulphate being formed by the oxidation of the ferrous sulphide present.

THIOSULPHATE. After the sulphide has disappeared thiosulphate may be recognized by the precipitate formed with silver nitrate, which is white at first, but which quickly turns yellow, then brown and eventually black. This compound was tested for occasionally and found to be present. As stated already it is a secondary product formed by the oxidation of potassium sulphide.

THIOCYANATE (Sulphocyanate, sulphocyanide). This compound was tested for occasionally and found to be present, the intense red coloration produced by ferric chloride in hydrochloric acid solution and destroyed by mercury perchloride being relied upon for its identification.

IRON. Iron in the ferrous condition was always present in the solid residue from the first, and also generally was present as the merest trace in the solution. After a time some of this ferrous iron became oxidized and ferric iron made its appearance, first in the solid matter and at a later stage in the solution. The earliest period at which ferric iron was found in the solid matter was after 28 hours and in the solution after 33 days. On one occasion a trace of brown, most probably rust, was seen in the barrel after 24 hours, but this was not tested, as it was desired to continue the observations. Since the production of rust is dependent upon the moisture that can gain access to the gun barrel, the humidity of the atmosphere is an important factor in conditioning the length of time that elapses before this compound is formed.

NITRITE. This was never found earlier than after a lapse of four hours and generally did not appear for five hours. Nitrite, however, is decomposed in the presence of alkaline sulphide and hence it did not occur until the sulphide had disappeared or had practically disappeared, when a small amount was always found.

NITRATE. This was never present on any occasion, even after the sulphide had disappeared.

ALKALINITY. Alkalinity to phenolphthalein was always present up to periods of sixty days, beyond which the experiments were not carried.

Taylor states [1] that the solution becomes neutral and Waddell says that it may not show any alkaline reaction,[2] but this was never the case in the experiments made, although after two months the alkalinity to phenolphthalein appeared to be less than after shorter periods. This may be accounted for by assuming that part of the potassium carbonate had become converted into bicarbonate which is not alkaline to phenolphthalein (the indicator used for testing), though alkaline to methyl orange.

It is not claimed that the above results necessarily represent those found under all conditions, since slight variations in the powder and the cartridges and particularly in the atmospheric conditions influence the nature and duration of the compounds formed. One very important fact in actual practice which frequently is not taken into account is that all theoretical conclusions are liable to be invalidated if the firearm were foul before it was fired.

Smokeless Powder. Smokeless (nitro) powder as used in firearms varies very much in composition. The principal ingredient and sometimes the only one is nitrocellulose (gun cotton). Another frequent constituent is nitroglycerine; thus ballistite consists essentially of nitrocellulose and nitroglycerine, cordite contains nitrocellulose, nitroglycerine and a little mineral jelly (vaseline), and axite (a pre-war powder) consisted of nitrocellulose, nitroglycerine, mineral jelly (vaseline) and a small proportion of potassium nitrate and barium nitrate. Potassium nitrate and barium nitrate are not uncommon constituents of smokeless powders, the proportion of potassium nitrate present in different powders varying from about 1 to about 6 per cent. and that of barium nitrate from about 6 to about 29 per cent.; thus ordinary Schultze powder [3] consists of nitrocellulose, potassium nitrate, barium nitrate and mineral jelly (vaseline). Amberite [3] consists of nitrocellulose, potassium nitrate, barium nitrate, wood meal and mineral jelly (vaseline). One variety of French smokeless powder contains both ammonium and potassium dichromates. It follows therefore that with such varying composition the nature and amount of the products formed also must show considerable differences. The principal gaseous products are carbon dioxide, carbon monoxide, hydrogen and nitrogen. The nature of the solid products differs with the composition of the powder, but nitrate, nitrite and sulphate are frequently found. Any graphite used for coating the powder is left partly unconsumed.

From what has been stated it will be recognized readily that the difference in the nature of the products of combustion of black powder and smokeless

[1] F. J. Smith, *Taylor's Principles and Practice of Medical Jurisprudence*, 1920, **1**, p. 558.
[2] L. A. Waddell, *Lyon's Medical Jurisprudence for India*, 1914, p. 111.
[3] This figured in the Monson shooting case.

powder[1] respectively is considerable, and hence there is no difficulty whatever in ascertaining which of the two kinds of powder has been used, though it is not always possible to determine the variety of the smokeless powder. Since, too, the variation in composition of different smokeless powders is so great, it is manifest that there must also be considerable variations in the products of combustion and, this being so, it is misleading to group all such powders together and to discuss them as though the differences were trifling and not more than those existing between different makes of black powder.

A number of experiments were made by me with various kinds of smokeless powder. The cartridges used were Ballistite, Bonax,[2] Cordite, Eley "Grand Prix,"[2] Nobel's "Empire," Primax, Remington, Schultze and Walsrode respectively.[3] The greater number of the experiments, however, were carried out either with Schultze powder or Remington powder, the latter of which consists essentially of nitrocellulose.

The differences between the results given by the smokeless powders and those given by black powder were considerable, the two most important being, first that smokeless powder did not give that intense black coloration in the interior of the barrel that is so characteristic of black powder, and second that with the smokeless powders both sulphuretted hydrogen and sulphide were absent. The principal results obtained may be summarized briefly as follows :

A characteristic smell was present after firing and decreased in intensity with lapse of time : this smell differed from that given by black powder.

Sulphuretted hydrogen in the gaseous state was absent.

A slight deposit, generally black or dark grey in colour, was noticed at the muzzle end of the barrel immediately after firing : this deposit was never of the intense black colour produced by ordinary gunpowder, though sufficiently dark to soil a clean white fabric introduced into the barrel. The colour did not become lighter with lapse of time as in the case of black powder. Only with Schultze powder and Eley "Grand Prix" cartridges were white particles, such as are mentioned by Taylor,[4] seen in the barrel. Traces of both ferrous and ferric iron were found sometimes in the solid matter immediately after firing.

The solution obtained by washing out the barrel with water was colourless or slightly brown, and contained a small amount of matter in suspension,

[1] Smokeless powder, although never naturally black is often blackened artificially by being coated with graphite.

[2] These are the names of loaded cartridges and not of powders, the nature of which was not determined.

[3] The experiments with cordite were made with a rifle : those with the other powders with a 12-bore shotgun and various sized shot, chiefly, however, No. 10. About 50 experiments were made altogether. The gun was cleaned well each time before use.

[4] F. J. Smith, *Taylor's Principles and Practice of Medical Jurisprudence*, 1920, **1**, p. 559.

generally of a light brown or light grey colour, but sometimes dark grey, and sometimes there was a slight black film (carbon) floating on the surface. This solution did not contain sulphide, but sometimes sulphate (only a trace, and never so much as with black powder), nitrite (always more than with black powder), and generally nitrate (varying from a trace to a considerable amount). The solution was neutral, which in view of the very general opinion that the fouling in firearms from which smokeless powder has been fired is acid, is noteworthy, and shows that the alkali found frequently in special oils recommended for cleaning purposes, if added to neutralize acidity, is unnecessary and its presence based on a wrong assumption. This is confirmed by the work of Huff published since the statement was first made in Legal Chemistry.[1] Huff states [2] that "The present high-pressure smokeless cartridge leaves no nitrocellulose residue and no corrosive acid residue. After-corrosion following the use of such cartridges is caused by the explosive deposition of a water-soluble salt or salts in whose aqueous solution steel corrodes, together with subsequent exposure to a high humidity and the presence of oxygen. In the present service ammunition this salt is potassium chloride from the decomposition of the chlorate in the primer." This is now recognized generally and the British War Office *Textbook of Small Arms* states [3] that the tendency of the barrels of small arms to become rusty after firing "is due to the products of combustion of the cap compositions. These compositions almost always contain chlorate of potash, which on firing, is converted into potassium chloride. Particles of this salt settle in the bore where they absorb moisture and cause rusting of the adjacent steel."

The different smokeless powders vary considerably in their effects on the barrel; thus a rifle from which axite has been fired may be left twenty-four hours without cleaning and no marked rusting occurs, whereas after using cordite the rifle must be cleaned at once, otherwise rust may be found the following day, even in a dry place like Cairo, while in a damp atmosphere, such as that of the sudd region of the Sudan, the rusting would be considerable.

No marked difference was found either in the composition or colour of the residue left in the barrel when examined immediately after the firearm had been discharged and when examined after various intervals of time had elapsed. It was noticed, however, that the amount of nitrate formed differed considerably with different powders; thus for instance ballistite gave less nitrate than did Nobel's "Empire," Schultze or Walsrode powders.

[1] A. Lucas, *Legal Chemistry and Scientific Criminal Investigation*, 1920, p. 130.
[2] W. J. Huff, "The Cause and Prevention of After-Corrosion on the Bores of Firearms," *Ind. and Eng. Chem.*, 12 (1920), pp. 862–70. Also van Pittius, *Zeitsch. angew. Chem.*, 1906, p. 848.
[3] War Office, *Textbook of Small Arms*, 1929, p. 220.

This might provide useful negative evidence and it might be possible to prove that a certain kind of powder that was suspected had not been used. Such substances as compounds of barium, chromium or potassium if present would provide useful indications of the nature of the powder.

Examination of Fouling. On the receipt of a firearm the first thing to be done is to note whether there is any smell at the muzzle end and, if so, its nature and intensity. Sulphuretted hydrogen is then tested for (except in the case of military rifles and self-loading pistols, where on account of the use of smokeless powder it does not occur) by means of lead test paper, first at the muzzle end and afterwards at the breech.[1] If there is not any indication of sulphuretted hydrogen at either end, the barrel should be blown through gently from the muzzle end, preferably by means of a small rubber bulb, while the test paper is inserted at the breech. The condition of the interior of the barrel, whether, for instance, it is clean, whether oiled, whether there is any sign of metallic fouling, of rust or of unburnt powder grains at the muzzle end should be ascertained next. If powder grains are found they should be detached carefully and their nature determined. In the case of a revolver, the condition of the chambers in the cylinder as well as the condition of the barrel should be noted. When nitro-powder is used in a revolver unburned particles are often left both in the chambers and in the barrel.

After the preliminary examination, the firearm should be held in a slanting position and a small quantity of distilled water [2] poured down the barrel from the breech end, a little at a time, an effort being made by turning the firearm to reach the whole area of the inside of the barrel. A receptacle to receive the water as it comes out is placed at the muzzle end. An alternative method is to swab out the barrel with wet cotton wool, which is then squeezed and the solution obtained examined, but the direct washing out with water is more satisfactory. In the laboratory a wash-bottle or pipette from which to deliver the water, and a small beaker in which to receive the washings, will be found convenient, but away from the laboratory small glass bottles with glass funnels make convenient receptacles. As a rule for rifles and shotguns about twenty cubic centimetres of water are sufficient, and about half this amount for revolvers and pistols. The water that has been through the barrel a first time should be passed through once or twice again, the firearm being turned and held in a different position each time, so that all sides of the interior of the barrel are well washed. It is better not to cork the barrel and not to try and shake the solution in the barrel, as

[1] Since sulphuretted hydrogen, if present, disappears very quickly when the breech is opened and the empty cartridge case removed, this should not be done until the test paper is ready to be applied.

[2] Boiling water, being a better solvent than cold water, is to be preferred whenever possible.

this invariably leads to loss. The colour, appearance and smell of the solution should be noted, and then it should be filtered. A small portion of the filtered solution should be tested for reaction to phenolphthalein and another small portion for sulphide (with acetate of lead). A further portion is acidified with hydrochloric acid [1] and tested for sulphate (with barium chloride), ferrous iron (with potassium ferricyanide) and ferric iron (with potassium thiocyanate). Another portion should be tested for nitrite and a further portion for nitrate. The colour of the residue on the filter paper should be noted and this residue should be treated with strong hydrochloric acid [1] and the solution obtained tested for ferrous iron (with potassium ferricyanide) and ferric iron (with potassium thiocyanate).

The test for nitrite recommended is by means of (*a*) sulphanilic acid and (*b*) napthylamine hydrochloride.[2] A solution of (*a*) is made by dissolving 0·8 gram of sulphanilic acid in 100 c.c. of water containing 5 c.c. of strong hydrochloric acid. A solution of (*b*) is made by dissolving 0·5 gram of napthylamine hydrochloride in 100 c.c. of water containing 0·8 c.c. of strong hydrochloric acid. The test is carried out by taking 10 c.c. of the solution to be tested, adding 0·2 c.c. of solution (*a*) followed by 0·2 c.c. of solution (*b*), mixing, covering and allowing to stand for 30 minutes, when if nitrite is present a pink colour will develop. It should not be forgotten that nitrites are sometimes present in the air, especially when coal gas is burned, so a blank test should always be made at the same time.

Another test is by means of a reagent consisting of dimethylaniline and sulphanilic acid, which is prepared by dissolving 1·0 gram of the former and 1·5 grams of the latter in 100 c.c. N/2 hydrochloric acid. Two drops of the reagent are added to 10 c.c. of the solution to be tested : in the presence of nitrite a red colour is produced. Alternatively the test may be applied on a filter paper or in a Nessler glass.[3]

The test for nitrate recommended is by means of phenolsulphonic acid and ammonia. The phenolsulphonic acid is made by mixing 3 grams of pure phenol in crystals with 37 grams of pure strong sulphuric acid (free from both nitric and nitrous acids) and heating on a boiling water bath for six hours when phenol-disulphonic acid is produced. To carry out the test evaporate 10 c.c. of the solution to be tested to dryness in a small platinum or porcelain basin ; add 0·2 c.c. of phenolsulphonic acid ; allow

[1] The freedom of this acid from iron compounds should be confirmed by a blank experiment.

[2] An alternative reagent may be made as follows : (*a*) 0·5 gram of sulphanilic acid is dissolved with slight warming in 150 c.c. of a solution of 70 c.c. of glacial acetic acid in 500 c.c. of water : (*b*) 0·1 gram of alpha-naphthylamine is boiled for a few minutes in 20 c.c. of water and this is poured into 150 c.c. of a solution of 70 c.c. of glacial acetic acid in 500 c.c. of water. Immediately before use 5 c.c. each of (*a*) and (*b*) are mixed and added to the solution to be tested.

[3] J. C. Giblin and G. Chapman, *Analyst*, **61** (1936), p. 686.

to stand for a few minutes ; transfer to a small beaker by means of a jet of water from a wash-bottle (using the minimum amount of water possible) and add strong ammonia in excess. If nitrate is present an intense yellow colour is formed. Any brown colour should be disregarded.

The tests for nitrate with diphenylamine, brucine in strong sulphuric acid, or nitron, often employed, are not so satisfactory as that recommended with phenolsulphonic acid, since diphenylamine gives a similar reaction to that for nitrates with nitrites, ferric salts and many other substances ; brucine gives a similar test to that for nitrates with nitrites under certain conditions and the sulphuric acid used with the brucine, unless specially pure, gives the reaction in the absence of nitrates and nitron gives a similar reaction to that for nitrates with nitrites, thiocyanates and various other compounds.[1] [2]

All the reagents (phenolsulphonic acid, diphenylamine, brucine and nitron) react with chlorates in the same manner as with nitrates and hence, if the presence of chlorates is suspected (which however is most unlikely with gunpowder, though it is sometimes present in blasting explosives and often in amateur-made bombs), this should be tested for [3] and, if present, the nitrate test becomes unreliable. To test for nitrate in the presence of a large quantity of chlorate, treat the mixed solution with sodium carbonate in excess, evaporate to dryness, ignite gently for some time to convert the chlorate into chloride and test the final residue for nitrate.

All the tests mentioned except that for nitrate, which requires evaporation, can be carried out in a few minutes almost anywhere. If it is necessary to test for nitrate away from the laboratory, the " brown ring " test with ferrous sulphate may be applied, although strong sulphuric acid,[4] which is required for the test, is not a satisfactory reagent to carry about. This test may be done either in a small test tube or by mixing a drop of the solution to be tested with a drop of a solution of ferrous sulphate on a white tile and touching the mixed drop at the edge with a drop of strong sulphuric acid.[4] If nitrate be present a brown colour develops where the solutions meet. The test solutions, except sulphuric acid, which should be in a glass-stoppered bottle, may be carried in small corked bottles (about 15 c.c. capacity), and the whole outfit may be packed into a very small compass.

Hans Gross states that the examination is " so simple that it may be employed if necessary in the country by any doctor or hospital assistant."

[1] I. Castellanos and R. Plasencia, " The Paraffin Gauntlet : a new Technique for the Dermo-Nitrate Test," *Journal of Criminal Law and Criminology*, 32 (1941), pp. 465–467.

[2] I. Castellanos, " Dermo-Nitrate Test in Cuba," *Journal of Criminal Law and Criminology*, 33 (1943), pp. 482–486.

[3] See pp. 151–152.

[4] The sulphuric acid should be tested before use to make sure that it is free from nitrous and nitric acids.

Although the testing of firearms like everything else is easy enough when one knows how to do it, nevertheless it should not be undertaken except by an experienced analyst.

Condition, Calibre and Marks. After the fouling has been tested, the weapon should next be examined for state of repair, working condition,[1] calibre, manufacturer's marks, country of origin and proof marks, all of which should at once be recorded.

Firearms are described as being of such and such a " bore " or " calibre," which in smooth bore weapons is the diameter of the hole in the barrel and in rifled arms the diameter of this hole before it was rifled, or, what is the same thing, the diameter of the barrel across the lands and, except with shotguns and large bore sporting rifles, this is expressed either in decimal fractions of an inch (British and American sizes) or in millimetres (European continental sizes). In the case of shotguns and large bore sporting rifles the British size is expressed by the word " bore " with a number (which varies from 4 to 32) prefixed, this latter being an old nomenclature indicating the number of spherical balls of lead, each exactly fitting the bore, that would weigh a pound. The stated bore or calibre, however, is merely a trade description and only nominal and approximate and not the precise size of the hole in the barrel since in manufacture it is impossible to make two barrels absolutely identical and hence there are always slight variations from the nominal size, for which certain small limits of tolerance are allowed. The calibre is determined best by means of a set of barrel gauges or from a cast of the barrel measured with a micrometer gauge.

Rifling. The rifling of a firearm consisted of a number of extremely shallow groves cut spirally in the interior surface of the barrel in order to enable an elongated, instead of a round, bullet to be used, to grip the bullet and to impart to it a rotatory motion that keeps it point foremost and thus adds to its steadiness on flight. The grooves in different makes of weapons may vary in number, direction of twist (right [2] or left [3]), width, depth, nature of corners (whether rounded or not) and angle of spiral, and every barrel of a rifled arm may leave the imprint of these features on the bullets fired through it. The portions of the original barrel surface between the grooves are termed " lands," the number of which is necessarily the same as that of the grooves. The width of the lands is generally less

[1] G. Burrard (*The Identification of Firearms and Forensic Ballistics*, pp. 88–106) discusses the subjects of the accidental discharge of a gun and the testing of trigger pulls.

[2] A twist that imparts to the bullet a spin in the direction similar to that of the hands of a clock.

[3] A twist that imparts to the bullet a spin in the direction contrary to that of the hands of a clock.

than that of the grooves except in barrels of small size and often much less, though in certain makes of weapons the lands and grooves are the same width.

The number of grooves in the military rifles of most nations is four, exceptions being the British rifle, which has five, and the Danish and Japanese, which have six.[1] In almost all rifles of all nations the twist of the rifling is right hand, exceptions being the British, French and Norwegian rifles, in all of which it is left hand. In the case of revolvers and self-loading pistols, too, the twist usually is right hand, well known exceptions, however, being the Colt weapons, the Bayard (Belgian) self-loading pistols and certain Spanish self-loading pistols, which have a left-hand twist. The number of grooves in revolvers and pistols usually varies from four to seven,[2] but may be as few as three or as many as eight. Three grooves are very uncommon [3] and the only weapons that can be traced having but three rifling grooves are the following-mentioned, namely, the British army Enfield rifle (1853) [4]; the British army Snider rifle (1867) [4]; the U.S. army Springfield rifle (1873) [5]; the former Schmidt-Rubin Swiss army rifle (1909) [6]; a small four-barrelled rim-fire pistol made by Tipping and Lawden [7]; the " Ranger 2 " ·32 revolver (Hopkins and Allen Arms Co., U.S.A.), with rim-fire and left twist,[8] and the " Warner Patent " ·32 revolver (Springfield, U.S.A.) with rim-fire and right twist,[8] the first five of which are obsolete. No record of any self-loading pistol with only three rifling grooves can be found. Weapons with eight rifling grooves also are uncommon and I have seen only one, a revolver. The muzzle-loading British " Brunswick " rifle (1839) had only two grooves and during the recent war a " No. 4 Mark II " rifle was produced having only two grooves.

It is impossible in a book of the size of the present one to give a representative list of different weapons showing the number of the rifling grooves and the direction of twist, even without other details, and anything short of this would only be " window-dressing " and not of much practical use, since the common weapons are well known and it is only the uncommon ones of which the details are difficult to find when required.[9] Also, the value of such a list, in my opinion, is often overrated because its function

[1] The Canadian Ross rifle has four grooves, which are much wider than the lands. The twist of the rifling is left-hand.

[2] See p. 223.

[3] The bullet with which Dr. Arlosoroff was killed at Tel Aviv, Palestine, in 1933, had only three rifling grooves, but the weapon that fired it was never traced.

[4] British War Office, *Textbook of Small Arms*, 1929, p. 5.

[5] W. H. Tschappat, " Early History of American Ordnance," *Army Ordnance*, **14** (1933), p. 79.

[6] British War Office, *Textbook of Small Arms*, 1909.

[7] I have examined two of these from a private collection.

[8] Kindly communicated by Colonel Calvin Goddard.

[9] The details of 16 different weapons are given incidentally on p. 249.

is misapprehended. Thus the knowledge derived from a list of manufacturing details, or from a collection of firearms, is not valuable because it may help in finding the weapon with which a particular crime has been committed, which it rarely does or can do, but because, after the weapon has been found and has been identified from the markings on the bullet or cartridge case with which the crime was committed, such a list or collection may provide information concerning the manufacturer and country of origin of the suspected weapon (not always marked on the weapon), the date when modifications (if any) were introduced into that particular type of weapon and possibly other details, some of which may be of importance and occasionally may lead to the ownership of the weapon being proved or disproved. During the early stages of an enquiry it might be of help to the police to know that a particular crime being investigated had been committed with a rifle and not with a revolver or self-loading pistol and it would certainly be of help in narrowing the scope of the enquiry if it were known that the rifle was of the army pattern, but such facts usually are obvious if the fatal bullet or cartridge case has been found. The knowledge, however, that the weapon was a revolver or self-loading pistol, as the case might be, or even to know the particular make of weapon, would not be of much value at this stage of the enquiry, since there are so many of both kinds and of the same makes in common use. Moreover, no matter how comprehensive lists or collections of firearms might be, and even if they included an example of all the weapons made by manufacturers of repute and of all the weapons made by large-scale manufacturers of cheap weapons, they would not and could not possibly include examples of the large number of weapons put together by small makers of cheap firearms in different parts of the world, much less examples of the occasional weapon assembled from parts of others by a private " gunsmith " and still less examples of all amateur-made weapons.[1] For instance in Egypt and Palestine cheap weapons (including many revolvers made to fire the Nagant ammunition,[2] though without the special Nagant mechanism [2] and with different and varied rifling), many of which originate in south-eastern Europe are fairly common and it would be very difficult, if not impossible, to obtain a complete list or specimens of all these. In the case of the weapon with which Dr. Arlosoroff was killed, already referred to, neither the lists nor the collections of firearms consulted enabled it to be traced.

As an indication of the dimensions and diversities of the grooves and lands in various weapons, it may be mentioned that in the British military

[1] See (*a*) N. Suskin, " Military Firearms Adapted by Criminals to Suit their Purpose," *American Journal of Police Science*, 1 (1930), pp. 549–64 : (*b*) J. S. Hatcher, *Textbook of Firearms Investigation, Identification and Evidence*, p. 12.

[2] See p. 214.

rifle the mean depth [1] of the grooves is 0·0065 inch (0·165 mm.), the width of the lands is 0·0936 inch (2·377 mm.) and the twist one turn in ten inches [2]; in the U.S.A. army automatic pistol (·45) the depth of the grooves is 0·003 inch (0·076 mm.), the width of the grooves 0·1522 inch (3·866 mm.), the width of the lands 0·072 inch (1·829 mm.) and the twist one turn in sixteen inches.[3] [4]

Marks and Irregularities in Barrel. When the bore of a new, well finished rifle firearm, made by a firm of repute, is examined carefully with a lens or barrelscope,[5] it is found that the smooth, glossy surface is by no means as perfect as it appears to the naked eye, but that there are generally, if not always, faint, narrow, longitudinal striations in the rifling grooves, to the edges of which they are parallel, and frequently, though not always, faint, narrow, circumferential markings across the lands. There are also usually innumerable faint marks, both in the grooves and on the lands, that are difficult to classify [6] and often, and possibly always, there is a narrow circumferential band of marks crossing both lands and grooves and extending completely round the bore very close to the muzzle end.

The narrow band of marks near the muzzle end has been found in revolvers and self-loading pistols of the best English, American and German makes, as also in weapons of other and various origins and, according to one well known English firm of manufacturers, who were good enough to reply to an enquiry on the subject, this marking is " due to small pieces of swarf getting between the bush and the barrel during the process of nosing the muzzle end of the barrel." This firm state that " we are changing our process in order to avoid this in the future." The only mention of this band of marks that can be traced is one by me in a previous edition of this book.

With respect to the origin of the other marks mentioned, experts differ. Certain of them attribute the longitudinal striations in the rifling grooves to the ever changing microscopic irregularities of the edge of the rifling cutter. Thus Goddard [7] states that " To the unaided eye the sharp edge of this tool appears perfectly even ; but actually, as in the case of a razor,

[1] The grooves may vary in depth at different parts of the barrel. Thus in one British military rifle the depth of the grooves ranges from 0·0055 inch, 14 inches from the muzzle, to 0·007 inch at the muzzle.

[2] War Office, *Textbook of Small Arms*, 1929, p. 45.

[3] C. O. Gunther, " Markings on Bullets and Shells fired from Small Arms," *Mechanical Engineering*, **52** (1930), p. 108.

[4] For groove diameters, see Clyde Baker, *Modern Gunsmithing*, pp. 232–233.

[5] See p. 199.

[6] In one revolver barrel examined (not of good make) there were well-defined rings at short intervals all the way down the bore, across both lands and grooves.

[7] C. H. Goddard, *Popular Science Monthly*, 1927, p. 22. See also J. D. and C. O. Gunther, *The Identification of Firearms*, pp. 266, 269, 275, 281, 287, 295. Many, if not all, of these quotations refer to Colonel Goddard's evidence in various trials.

the edge consists of a row of minute saw teeth, visible only under the microscope. These teeth leave microscopic scratches and ridges on the inner surface of the barrel. . . . Since no two rifling cutters can have little saw teeth exactly alike, no two pistol barrels can have exactly the same markings. Moreover, the edge of a cutter changes with every cut; hence, even if two barrels are rifled on the same machine and with the same tool, the markings they leave on bullets will differ." Hatcher says [1] that the cutter becomes abraded or roughened and has little pieces broken out of it and is never the same at the end of a stroke as at the beginning, nor is it the same for different grooves of the same barrel, and especially is it different for different barrels. Gorman states [2] that "The minute teeth on the fine edge are wearing down, chipping off in places, and the edge is scratching its ever changing pattern on the inner surface of the steel barrel. Another source of tell-tale bore markings is to be found in the slivers of steel that have been removed by the cutter and are constantly twirling around ahead of the cutter within the barrel. They not only create their scratch marks, but they also leave behind marks of 'fractures' at the point where the steel sliver breaks from the interior barrel surface." Gunther states [3] that the tool marks in the barrel of a firearm are not produced by the fine saw-like teeth on the edges of the tools employed, nor by the blunting of the tools during use, but by the tearing of the steel of the barrel by the tools, and he gives two photomicrographs of the same tool before and after hard use, which do not show any perceptible change in the appearance of the cutting edge and a further photomicrograph which shows the results of the tearing action. This expert considers the wearing of the tools a matter of small importance as a cause of that part of the individuality of firearms that is imparted to them during manufacture; he omits, however, to account either for the fine longitudinal striations in the rifling grooves, or for the fine circumferential marks on the lands.

With respect to the circumferential markings on the lands of a barrel Hatcher states [1] that the reaming of the barrel "leaves circular marks round and round the barrel, caused in part by irregularities of the cutting edge of the reamer and partly by little chips of steel that get caught by the reamer and drag around with it."

There can of course be no doubt whatever that both the longitudinal striations and the circumferential marks present in new barrels must have been caused by the reaming and rifling [4] operations respectively and by

[1] J. S. Hatcher, (*a*) *Army Ordnance*, **14** (1933), pp. 92–5; (*b*) *Textbook of Firearms Identification*, p. 275.

[2] S. F. Gorman, *Scientific American*, 1930, p. 266.

[3] J. D. and C. O. Gunther, *The Identification of Firearms*, pp. 27, 28, 267, 296, 315.

[4] The reamers widen to the required diameter the hole first drilled in the barrel, obliterating any previous marks left by the drill.

any finishing process, such as lapping,[1] employed and, although it is unfortunate that experts should differ as to the exact manner of their causation, this in no way affects the question whether or not they are the origin of certain markings on bullets, nor does it affect any value they may have in that respect.

As a weapon is used, so additional scratches and other marks are produced in the barrel, especially if this is not well looked after and cleaned carefully. Such marks include small spots and patches of rust strongly adherent to the barrel surface; pitting caused by rust that has been removed; marks and scratches due to careless cleaning; scratches from particles of grit; scoring caused by particles of metal cut by the edges of the lands of the barrel from the bullets (both metal-coated and naked lead) and metallic fouling consisting of the particles of the coating from coated bullets or of lead from lead bullets that have become temporarily wedged in the barrel (as may particularly happen when the barrel is rusted or pitted), or that have been fused to the surface of the barrel.

Any scoring in a barrel caused by particles of grit or of metal cut from the bullets is a permanent feature of the barrel that may, and usually does, mark the bullets and such marks should be distinguished from those made directly on the bullets by similar particles of grit or metal.

It is sometimes denied that the metal from a bullet, even if cupro-nickel coated, and more particularly when it is naked lead, can score a steel barrel, though if a candle can be shot through a deal plank, as it may be, and if a piece of cotton waste placed between the two steel surfaces of the swing span of a large bridge will mark permanently the steel when the span is closed, as has happened, it is not extraordinary that lead, and much more cupro-nickel should be able to scratch a steel barrel under the very high temperature and pressure conditions prevailing when a shot is fired. The late Director of the National Physical laboratory, Teddington, kindly replying to an enquiry on the subject, stated that " if actual particles of the cupro-nickel jacket of the bullet could be detached these would certainly be capable of scratching the barrel badly," [2] and Burrard, with reference to the effects of lead bullets on a steel barrel, says, " my own personal view is that lead bullets can, and do, produce these changes in the secondary markings." [3]

So far, weapons of good quality only have been considered, but there are in existence immense numbers of cheap, badly made and poorly finished firearms and even amateur-made ones, in which naturally the tool-marks are more pronounced and irregularities and imperfections are more common,

[1] Burrard states that " in the great majority of self-loading pistols and in all cheap revolvers, the barrels receive no final polishing and are left just as they come off the rifling machine." (*Forensic Balistics*, p. 163.) Gunther says, " In general, barrels designed primarily for use with metal-jacketed bullets are not lapped." (*The Identification of Firearms*, p. 54.) This means that the finishing tools employed by the best manufacturers are now so efficient that lapping is often unnecessary.

[2] Private letter. [3] Private letter.

a few examples of which may be given. Thus Pollard mentions [1] a case in which the foresight of a cheap revolver had been made by screwing a pin into the barrel, which projecting slightly inside, marked the bullets in a characteristic manner: I have examined a practically new, cheap revolver in which the bottom of the foresight (which was in the form of a rounded boss without sharp edges) projected into the barrel and marked the bullets: [2] one of the pistols employed for the murder of the Sirdar of the Egyptian army (Sir Lee Stack) had a fault at the muzzle end of the barrel that produced a distinctive mark on the bullets [3]: Gunther records a case in which the breech end of one of the lands of a barrel had a number of tiny teeth that scored the bullets [4] and in another case on record one of the rifling grooves of a firearm was double the width of the others.[5] It has been stated, too, that at a certain town in Spain rifling was "being done with a hand punch, barrels rifled only one inch each way from the apertures, and the rifling sometimes varying at the two ends." [6]

As a firearm is used, not only do fresh marks appear, due to the various causes enumerated, but the barrel also is subjected necessarily to erosion [7] from (*a*) the friction of the bullet as it passes through; (*b*) the propellent gas (which has a very high temperature and velocity) as it leaks over and round the bullet. ("The rush of gas at so high a temperature causes a slight volatilization and a 'washing away' of the metal," [8] the effect of which is particularly noticeable at the breech end) and (*c*) mechanical cleaning, which enlarges the bore at the end from which it is usually cleaned, generally the muzzle. (In the case of British service ·303 rifles "which have fired ten or twenty thousand rounds of proof and have never been cleaned with anything but ammonia" the "·305 plug will not run through them, whereas barrels which have been in barracks for five years and have only fired perhaps 1000 rounds will often permit the 0·308 plug to run right through." [9]). Mechanical cleaning also may obliterate, partly or wholly, one set of marks and may produce others.

Thus three effects result from use, the enlargement of the bore; the partial or total effacement of the original secondary marks and the production of fresh marks. Burrard considers "200 rounds as the absolute minimum number of rounds required to enlarge the bore of a ·303 rifle

[1] H. Pollard, "What the Bullet Tells," *Discovery*, 5 (1924), p. 281.
[2] See pp. 223–224, weapon J.
[3] Sydney Smith, "The Identification of Firearms and Projectiles," *The Police Journal*, 1 (1928), p. 419.
[4] C. O. Gunther, *Mechanical Engineering*, 52 (1930), p. 109; also J. D. and C. O. Gunther, *The Identification of Firearms*, p. 45.
[5] G. Burrard, *The Identification of Firearms and Forensic Ballistics*, p. 185.
[6] Wesley W. Stout, "Finger Printing Bullets, The Silent Witness," *Saturday Evening Post*, June 13th and 20th, 1925.
[7] War Office, *Textbook of Small Arms*, 1929, pp. 57, 157, 360.
[8] War Office, *op. cit.*, p. 157. [9] War Office, *op. cit.*, p. 360.

by ·0001 of an inch. This number could be more than doubled in the case of any ordinary self-loading pistol before a similar enlargement could be produced," [1] and " It can therefore be accepted that the major characteristics of the bore cannot be changed by wear produced by firing any ordinary number of test rounds in a suspect weapon." [2] " But wear can, and does have a decided effect on the minute markings on the surface of the bore which causes the finer striations in the engraving of a fired bullet." [3] In order to test this, Burrard carried out a number of special experiments, as a result of which he concludes that " in the case of a revolver firing lead bullets, fifty rounds is sufficient to change completely the finer striations in the engraving " and that " In the case of self-loading pistols firing nickel-jacketed bullets the change seems to be brought about more rapidly, and a series of but twenty-five rounds proved sufficient to change completely the finer striations in the engraving produced by a 7·63 mm. Mauser self-loading pistol."[3] Burrard also says " I feel certain in my own mind that no barrel can be relied upon to produce identical engraving after twenty rounds have been fired through it." [3] Gunther states that with a particular firearm (kind not stated) no change had occurred in the elements of identity after 100 rounds had been fired, but he mentions that erosion may take place more rapidly in some instances than in others.[4] I have found characteristic features remaining in certain barrels after firing twenty rounds,[5] but the experiments were not carried further.

Thus the condition of the inner surface of a barrel of a firearm is constantly undergoing change and, although it is usual to refer to some of the markings as " permanent characteristics " of the barrel in which they occur, actually none of the secondary markings is permanent and even such primary characteristics as the rifling are liable to alteration and in the barrels of poor quality weapons, that are ill used and neglected, the rifling grooves may become so choked with rust or metallic fouling and the lands may be so worn that occasionally barrels are found in which the rifling cannot be seen and in which it is impossible to determine the number of rifling grooves originally present.

No matter what the origin of the secondary marks in the barrel of a firearm may be, whether they are tool marks, or are due to lapping, rust, cleaning, accident, or to particles of grit or of metal from the bullets, they all may mark the bullets and they are all individual and characteristic for each particular barrel, being in fact " gun prints " of the barrel, which, like finger prints, are never duplicated.

Examination of Barrel. There are two methods of examining the

[1] G. Burrard, *op. cit.*, p. 168.
[2] G. Burrard, *op. cit.*, pp. 168–9.
[3] G. Burrard, *op. cit.*, p. 169.
[4] J. D. and C. O. Gunther, *op. cit.*, p. 93.
[5] See p. 224.

interior of the barrel of a firearm, one direct and the other indirect. In the direct method, as the name indicates, the barrel is viewed directly, either with the naked eye, or by means of a single lens or a combination of lenses. If the barrel is dismounted one end is held to the light, or if not dismounted, the light is reflected into it by means of a small mirror, or a piece of white paper or white cardboard placed against the breech face, or, better still, a tiny cylindrical electric lamp, such as the indicator lamps used for telephone switch boards, is introduced into the breech end. The lamp used by me is 4 mm. in diameter and is used with a 4·5 volt flashlamp battery. The interior of the barrel is strongly illuminated and may be inspected in detail and, if required, the muzzle end may be photographed.

Of the various lenses and instruments for the examination of gun barrels tried, I have found a " Barrelscope,"[1] which is a kind of telescope, gives the best results. Instruments of the cystoscope[2] type (of which there are several different kinds) also are made for the examination of the barrels of firearms and are provided with a small electric lamp and sometimes also with a camera. I have had an opportunity of using only one of these and my experience with it has been but small, but it was not found of much practical value, though it might be useful for the detailed examination of some one specific irregularity. In the indirect method, either a cast of the interior of the barrel is made and examined, or the markings in the barrel are reproduced on bullets specially fired through it.

Each of the two methods, the direct and the indirect, has its uses and both should be employed, if possible. The direct method is particularly useful for an examination of the marks, irregularities, rust or fouling, but naturally the results cannot be shown in Court unless they are photographed. The pitch, too, may be determined,[3] though this may be found more readily from a rolling made from a cast. A cast makes a striking exhibit in Court and from it, not only the calibre of the weapon, but also the depth and width of the grooves and the width of the lands may be measured by suitable precise gauges or by means of a microscope fitted with a micrometer eye-piece. The features shown in the round on a cast may be reproduced on the flat by rolling it firmly on a perfectly smooth sheet of dentists' moulding composition, plasticine or thick lead foil[4] and from this, as already mentioned, the pitch may be determined and photographs may be made and enlarged for exhibition in Court. A cast, however, is of no value for the ordinary secondary markings in a barrel, since either these do not reproduce

[1] Made by Messrs. J. H. Steward, Ltd., London.

[2] A cystoscope is an instrument used for the examination of the human bladder.

[3] C. H. Goddard, " Scientific Examination of Firearms and Bullets," *Journal of Criminal Law and Criminology*, **18** (1926), pp. 258-9.

[4] The kind used in gold assay has been found satisfactory. See p. 230. Lead foil not only gives better results than the tin foil usually recommended, but also yields better photographs on account of the absence of reflections.

at all or do not reproduce well. Despite the many advantages of a cast, it is not always advisable to make one, since, even if permitted to do so by the Court in those instances in which the weapon has become a Court exhibit, the operation may lead to adverse criticism from the opposite side on the ground that the condition of the barrel has been changed and thereby it has been rendered useless for experimental firing, as may well happen if the cast has not come away cleanly, since particles of sulphur, or of metal, left in the barrel might have to be removed by mechanical cleaning, which would entail considerable danger of scoring the barrel, thus vitiating all subsequent examination for secondary marks. Often, however, a cast of the barrel of a weapon of the same make, calibre and rifling is equally satisfactory for demonstration purposes in Court.

Cast of Barrel. For making the cast of a barrel, sulphur is generally employed, but sulphur casts suffer from the disability of being very brittle and easily broken [1] and other materials, such as fusible alloy, lead, type metal and tin are better.[2]

In the case of a rifle, or other long barrel, it is neither necessary, nor ordinarily possible, to make a cast of the whole barrel, one of two to three inches of the muzzle end being sufficient, but with small revolvers the cast should be of the whole length of the barrel, except a few millimetres at the breech end, which should be left free in order to facilitate the extraction, and with large revolvers the cast should be of the greater part of the barrel and particularly of the muzzle end. In the case of self-loading pistols the cast should exclude the chamber, since this is not required and, if included, it would prevent the cast from being removed from the muzzle on account of the greater diameter of the chamber as compared with that of the barrel.

To make a cast, the barrel, whenever possible, should be removed and the bore well oiled. The material used for casting should be poured in at the breech end, otherwise the extreme muzzle end, which is the more important of the two from the point of view of the markings, may escape reproduction, and for the same reason the muzzle end of the barrel should not be plugged inside. As a rule the barrel should be stood on a stone or metal slab with the breech end uppermost while the cast is being made. The one important principle, on the observance of which success largely depends, is that the barrel should not be allowed to become hotter than is necessary and, therefore, that the casting material should not be heated

[1] During the Sacco-Vanzetti trial one witness stated with respect to a sulphur cast that in his opinion " little flakes have been knocked off." (J. D. and C. O. Gunther, *The Identification of Firearms*, p. 154.)

[2] Dr Martin recommends a waxy material (Celerit) mixed with blacklead. F. W. Martin, " A Simple Method of Taking Casts of Fire-arm Barrels," *The Police Journal*, 9 (1936), pp. 72–73.

unduly. Also, the cast should be forced out as soon as it has solidified sufficiently to allow of this being done and before the barrel has become cold.

Sulphur Casts. The sulphur should be of the roll variety, broken into small pieces, and a small amount (the capacity of a revolver or pistol barrel is only small) should be melted over a gas flame or spirit lamp.[1] The sulphur must not be heated too strongly, as at 180° C. (367° F.) it becomes thick and dark coloured. The best temperature is as close to the melting-point (113° C., 235·4° F.) as possible, when it is in the condition of a clear yellow liquid and, in order that this temperature should not be exceeded, it is better to put into the vessel an excess of sulphur above that required for the cast and to use the material when a sufficient quantity has become liquid before the whole has melted. The sulphur should be poured into the barrel (at the breech end) slowly in order to avoid air bubbles and, as already mentioned, the cast should be forced out (from the muzzle end by pressure applied at the breech end) as soon as it becomes solid enough for this to be done. Often the extraction of the cast without breaking is difficult, especially with barrels that are deeply pitted. This, however, may usually be done by applying at the breech end a cylindrical rod of metal, that just fits into the barrel, and gently tapping with a small hammer. The extraction may be made much easier by putting into the centre of the barrel, before pouring in the liquid sulphur or other material, a double piece of stout copper wire *loosely* twisted. This serves as a handle and permits the cast to be given a slight turn in the direction of the twist of the rifling.

Metal Casts. Wood's metal[2] (melting-point 68° C. (154·4° F.)) tin (melting-point 232° C. (449·6° F.)); lead (melting-point 325· C. (617· F.)) plumber's solder and type metal[3] are all easily melted,[4] especially Wood's metal. On account of the fact that antimony expands on cooling, the casts made with type metal, which contains antimony, are particularly clear and distinct, but they are difficult to extract and Wood's metal, which gives very good results, is recommended.

Diagram. An excellent exhibit for showing in Court is a diagram of a cross-section of the barrel of a suspected weapon and one of a cross-section of the crime bullet, drawn side by side with ink on paper, both to the same scale, an enlargement of ten diameters usually being the best size.

Experimental Shooting. There still remains for consideration the method of ascertaining the nature of the markings in the barrel of a firearm by firing

[1] I have found the smallest size of the tin-lined copper pots with long handles, as used in Egypt for making coffee, very satisfactory.

[2] A mixture of cadmium (1 part), tin (1 part), lead (2 parts) and bismuth (4 parts).

[3] A mixture of tin (5 parts), antimony (20 parts) and lead (75 parts). The melting-point of this cannot be traced.

[4] A similar small pot to that recommended for melting sulphur may be employed.

bullets through the barrel and examining the markings produced on the bullets. This is the most satisfactory of all the methods for the purpose in view, since the markings in a barrel are only of interest in so far as they affect the bullet, and the imprint it receives is not such as is given by a cast, even if it were possible to reproduce the finer markings on a cast, which it is not, but it is a composite of the marks in the barrel, one after and on top of another, with a final top print of the markings at the muzzle end.

The comparison cartridges for the experimental firing should be of the same kind, size, make and, if possible, of the same or about the same age as those used for the crime.

I have tried a number of materials including soft rags, fine sifted earth, water and different kinds of cotton for the reception of the fired bullets, so as not to injure them, and have found ginned cotton (cotton without the seeds) of good quality (not cotton waste) such as is used for filling mattresses, bolsters and pillows, to be the best and when, as has happened several times, it has been necessary to obtain comparison bullets at short notice with improvised accessories, cotton has always been readily procurable and enclosed in a piece of cotton fabric and tied up into the shape of a pillow or put in a sack about 4 feet long and fired into lengthwise has proved excellent and even with rifles, two such sacks placed end to end and fired into from a distance of thirty yards have proved sufficient. On one occasion a sack filled with discarded woollen stockings gave excellent results, and on another occasion a sack filled with old clothes was not very satisfactory on account of the buttons. Hatcher suggests placing the muzzle of the weapon within a few inches of the cotton,[1] whereas Gunther says that, although for smokeless powder the weapon may be held close to the cotton for black or semi-smokeless powder it must be between three to five feet away.[2] In one instance in my experience, when using very old ammunition loaded with smokeless powder, a long flame issued from the muzzle of the revolver employed,[3] which would have fired the cotton had the weapon been close.

If the cartridges are stamped on the base (as they are often) with the initials of the manufacturer or other marks, they should be put into the weapon with these marks in the same position (which should be noted) each time, so that the comparison of the fired cases may be simplified and, if the cartridges are not marked, they should have a small mark scratched on them and should be placed in the weapon with this mark at the exact middle of the top. Also, the nose of each bullet should be nicked at the exact middle of the top, so as to facilitate the subsequent comparison.[4]

[1] J. S. Hatcher, *Army Ordnance* (1933), p. 95.
[2] J. D. and C. O. Gunther, *The Identification of Firearms*, p. 55.
[3] See p. 234.
[4] For the recovery of bullets from rifles, see D. W. Rife, " Recovery of Bullets from High Speed Ammunition," *The Journal of Criminal Law and Criminology*, 30 (1939), pp. 379–385 ; also *The Police Journal*, 13 (1940), pp. 73–79.

Both the cartridge case and the bullet should have scratched on them a distinguishing letter to indicate the weapon used and sometimes also a number denoting the order in which the shot was fired. This is best done before firing, though, if the bullets are retrieved one by one in the order fired, the marking may be done as they are collected, and the cases may be marked one by one as they are taken out of the weapon or picked up after ejection.

The marking on the bullets should be either on the nose or on the lead at the base, or on both, and on the cartridge cases near where the bullet fits in and never on the head. The marking is best done by means of a fine steel point fixed in a handle.

Striker. The nose of the striker (firing pin, hammer) that explodes the cap of the cartridge makes on this an indentation that usually reproduces, not only its own shape, but also the minute irregularities on the surface, such as file marks and pitting, which differ for every striker; thus, for instance, the marks made by the two strikers of a double-barrel gun are not the same. The shape and condition of the nose of the striker can be examined satisfactorily only by the microscope and are best shown to others by means of photomicrographs, an impression in wax, or other medium, sometimes recommended, not being of much use for comparison purposes, since it may not be identical in all its details with those produced on a comparison cap by firing, owing to the modifying effects of the internal gas pressure in the cap. In a certain murder trial [1] reported the marks left on the cap of an empty cartridge case found on the scene of the crime were very characteristic and were matched by those on the striker of the rifle of the accused person.

Breech Face. The face of the breech shield (breech block), or in rifles the bolt head, of a firearm, which seals the breech end of the chamber and against which the cartridge case is driven by the pressure of the gas generated on firing, is scored generally by file marks or machine marks produced during manufacture and sometimes also by additional marks made subsequently, for instance by the end of the cleaning rod or by rust, and these, which are distinctive for every different weapon, are imprinted usually on the soft metal of the cartridge case and cap, particularly on the latter, when the weapon is fired. When, however, as sometimes happens, the breech face, or bolt head, is oily, or dirty, or both, the cartridge case may not take all, or even any of the marks. Sometimes, too, the first few experimental shots may fail to take the marks while later shots are well marked. The marks on the breech face or bolt head should be examined microscopically

[1] G. W. Baker, "Scientific Evidence Relating to Firearms with Special Reference to a Recent Murder Trial," *Analyst*, 55 (1930), pp. 740–1.

and an enlarged photograph or photomicrograph made, as this will be found helpful, not only for comparison purposes, but also for exhibition in Court. If the barrel cannot be removed the breech face may be examined through the barrel by means of a barrelscope.[1] When the breech face cannot be photographed directly, it may be photographed through a prism as described by Hatcher,[2] or a mould of it may be made in celluloid as described by Moritz [3] and this may be photographed. In the Browne and Kennedy case certain markings on the breech face of one of Browne's revolvers were reproduced on the cap of a fired cartridge case found in the motor car from which the murder was committed.[4]

Extractor and Ejector. The functions of these two features of a firearm, as their names indicate, respectively is to extract and to eject the fired cartridge cases. There are two systems in use, one applied to revolvers and shotguns,[5] where one piece of mechanism performs the double function of extractor and ejector, and the other, applied to rifles and self-loading pistols, in which the extractor and ejector are separate. In the former, the empty case is pushed out backwards by the extractor, which fits behind the rim and is operated either automatically by the opening of the breech or by hand, the case usually not being marked or scratched by the operation ; in the latter, which in rifles is operated when the bolt is opened and drawn back and in self-loading pistols by the recoil, the empty case is gripped by the extractor, which is a small steel hook (claw) that engages in the groove and draws the case backwards until it is forced against a small steel projection, the ejector [6] (which varies in shape in different types of arms), that throws it clear of the weapon. Both the extractor and the ejector may, and usually do, mark the soft brass of the case, and as these marks occasionally may be distinctive and characteristic, both the extractor hook with the condition of its edge, and the ejector, should be examined. More generally however, the extractor and ejector marks indicate merely the type of weapon

[1] See p. 199.

[2] J. S. Hatcher, *Textbook of Firearms Investigation, Identification and Evidence*, p. 190.

[3] A. R. Moritz, *The Police Journal*, 11 (1938), pp. 364-369. See this book, p. 230.

[4] W. T. Shore, *Trial of F. G. Browne and W. H. Kennedy*, 1930, pp. 105-9 ; Figs. 1, 2, 3 (pp. 23, 24, 25).

[5] In many shotguns the empty case is only partly withdrawn by the extractor and must be removed by hand, but there are guns in which the case is ejected automatically clear of the weapon. With shotguns and occasionally with revolvers the extractor may mark the case just in front of the rim at the moment of firing and before extraction. This is not a scratch, such as is made by the claw of the extractor, but is caused by the gas pressure in the cartridge expanding the wall of the case just in front of the rim "until it receives an imprint of the junction of the extractor with the rest of the chamber" (G. Burrard, *The Identification of Firearms*, p. 125 ; Pl. XXI).

[6] Occasionally there are two ejectors, pistol L (p. 213) being an example. In a small proportion of self-loading pistols the striker, or the next cartridge in the magazine, or a part of the magazine acts as an ejector and no ejector mark is present on cartridge cases used in such weapons.

and not the particular weapon. The extractor marks one or both lips of the groove and often the groove, but in addition it may mark also the cylindrical surface of the case just in front of the groove ; the ejector marks the base of the case, or the edge of the base. The extractor and ejector marks usually are on opposite sides of the case. Extractor marks, however, may be produced on any cartridge that is in the chamber of a rifle or self-loading pistol by merely unloading without firing and in a certain trial where a military rifle was concerned it was suggested by the defence that the extractor marks on a fired cartridge case had been produced by practice loading and unloading.[1]

Distance of Ejection. The distance to which an empty cartridge case may be ejected is sometimes of importance, thus in one shooting incident with a British army ·303 rifle, where there was not any dispute about either the identity of the person shooting, or the rifle used, but only about the spot from which the firing took place, four empty cartridge cases which I identified as having been fired from the particular rifle, were found at distances varying from eight metres (26·2 feet) to twenty metres (65·6 feet) from the spot where the person shooting stated he was standing when he fired.

I made seven experiments with the rifle used for the shooting and found that the distances to which the empty cases were ejected varied from about one foot to about three feet.

The only references to the subject known to me in the standard works on firearms are to machine guns and self-loading pistols,[2] where the ejection is brought about by the firing and not by merely pulling a bolt after the firing has taken place, as in the British army rifle. Hatcher says [2] " The Thompson submachine gun throws them straight out to the right, usually from seven to twelve feet," and he says of the Colt ·45 automatic pistol that " The Government Model . . . as issued will throw the empties anywhere from nearly straight back to almost directly to the right, and the distance will be anywhere from almost under the gun to ten or twelve feet away." A diagram is also given showing the results of tests specially made with twelve different weapons, ten shots having been fired from each.

Magazine, Charger and Clip. In a rifle or self-loading pistol a small reserve of cartridges is stored in what is termed the " magazine " : in a revolver the reserve cartridges are kept in chambers in the cylinder.

In order to facilitate the loading of the magazine of a rifle this is filled either from a " charger " or from a " clip," which in both cases is a small metal holder (containing from three to six cartridges, but usually five) into

[1] G. W. Baker, *Analyst*, **55** (1930), p. 741.
[2] J. S. Hatcher, *Textbook of Firearms Investigation, Identification and Evidence*, 1935, pp. 236–238.

which the cartridges are inserted by hand and in which they are retained by being gripped near the base. Chargers and clips are essentially the same article called by different names because they are used in different manners. The military rifles of thirteen nations out of eighteen are provided with chargers and only five with clips.[1]

When a charger is used the cartridges are forced out of it into the magazine by hand, the empty charger falling away: when a clip is employed this, with its complement of cartridges, is placed in the magazine, the clip being retained until the last round is expended.

From the magazine the cartridges are fed automatically, as required, by means of a strong spring into the chamber of the weapon.

When a charger or clip is filled, and again when the cartridges are forced out, the sides of the cylindrical cases of the cartridges are liable to be scratched near the base. Again when the cartridges are forced out of the magazine into the chamber of the weapon the cases may be scratched by the lips of the magazine. In addition to the scratches mentioned, cartridge cases occasionally may be marked further, for instance, by grit or by some defect such as pitting, or by a hard deposit of carbon in the chamber. As a rule the scratches referred to are not characteristic, but since they may be so, they should be looked for and examined.

Up to the point when the cartridges are in the chamber ready for firing, any scratches they bear manifestly have not been made by the firing of the weapon and the cartridges may be unloaded and never fired, or they may be loaded again into and fired from the same weapon, or they may be loaded into and fired from a different weapon. Great care, therefore, is necessary in interpreting the scratches, or "scrapes," as Burrard calls them,[2] on the cylindrical surface of cartridge cases.

With both rifles and self-loading pistols a single cartridge, additional to any in the magazine, may be placed by hand directly in the chamber of the weapon and any such cartridge, therefore, will be free from scrapes due to the charger, clip or magazine, but they may be marked on the base when the breech is closed for firing by that part of the extractor (not the sharp edge of the claw) which projects slightly beyond the surface of the breech face or bolt head. In the case of rifles like the British army weapon, which have a "cut-off," if this is used, the upper side of the top cartridge in the magazine may be, and usually is, marked with a crosswise scrape.

Revolver cartridges, as a rule, are loaded directly by hand into the chambers of the cylinder, but occasionally they may be loaded from special clips,[3] [4] in

[1] British War Office, *Textbook of Small Arms*, 1929, pp. 403–7.
[2] G. Burrard, *op. cit.*, pp. 126–8.
[3] British War Office, *Textbook of Small Arms*, 1929, p. 90.
[4] Calvin Goddard, "The Valentine Day Massacre," *American Journal of Police Science*, 1 (1930), pp. 63–4.

which event they may be scratched by the edges of the clips, both when being put into the clip and when being forced out.

Chamber. The chamber of a rifle, self-loading pistol or shotgun is that part of the breech end of the barrel into which the cartridge fits when it is ready for firing; it is almost always of larger diameter than the bore, of which it is a continuation, being tapered off where it meets the bore, this taper in rifles being called the " leed " (lead) and in shotguns the " chamber-cone." In a revolver there are a number of chambers (usually five or six), which together constitute the cylinder, which is entirely separate from the barrel.

CARTRIDGES

The components of a cartridge are the cap or primer; the powder; the wads; the projectile (which is the most important feature and is the reason for the existence of the cartridge) and the containing case, all of which, except the powder (which has already been dealt with), now may be considered.

As cartridges are often found in connexion with a crime and as live cartridges must be examined and compared with projectiles and empty cases, a few points about them may be mentioned.[1]

Cartridges should be examined carefully and the kind of case, the dimensions and all marks indicating the manufacturer, date or size should be recorded. One or more should be opened and the bullet, pellets or slugs; the wads and the case should be measured and examined; the projectile weighed and sometimes analysed;[2] the number of pellets or slugs counted and the nature of the powder determined, a qualitative analysis generally being sufficient.

In a revolver, the position in the cylinder of any unfired cartridges and also and especially of any empty case or misfires should be recorded before the cylinder is unloaded. On several occasions in my experience this information was important.

The easiest way of extracting a bullet from a cartridge having a metal case, is to put the bullet, point downwards and wrapped in cloth to protect it from injury, in a small vice or clamp and to work the case gently from side to side until it is felt that the bullet is quite loose, when it is extracted with the fingers. Unfortunately, however, this almost always injures the bullet, no matter how carefully the operation is performed, and the only way of extracting a bullet without marking it, is to cut through the case, below the base of the bullet, with a small fret-saw or hack-saw and to peel off the portion of the case left adhering to the bullet with a small pair of

[1] See also J. S. Hatcher, *Textbook of Firearms Identification*, pp. 259–269.
[2] See pp. 235–238.

pliers. To examine a shotgun cartridge, this should be laid on its side and cut through about the centre with a sharp knife, if the case is cardboard, or with a saw if the case is metal (as it occasionally is), when the powder will be found in one half and the pellets or slugs in the other half, each kept in place by a wad.

The number of different kinds of cartridges is so large that it is impossible to describe or even to enumerate them, but full datails may be found in the manufacturers' catalogues. Care should be taken that live cartridges and also empty cases, that have been opened for experimental purposes and that still contain the unexploded cap, are not left about or thrown away where they might be picked up by children or others ; they should be destroyed by being shot off or thrown into a deep lake, a river or the sea.

Caps. A percussion cap, or primer, in its simplest form consists of a small cup or shell of copper or brass, sometimes nickel-plated, into which has been pressed a very small amount [1] of a priming or detonating mixture,[2] over which is placed a disc of tinfoil and a coat of varnish.

When the trigger of a firearm is pulled, the striker (firing pin, hammer) hits the cap causing an indentation in the soft metal (the metal side of the cap being outermost) which is then made more pronounced by the cartridge case being forced back by the gas pressure produced on firing, and the cap thus becomes marked permanently with the imprint of the nose of the pin and, since on this nose, as already explained, there are file marks and other marks made during manufacture or due to subsequent wear and tear, which are different for every striker, this imprint generally is as characteristic as a finger print and from it the identity of a particular firearm often may be established.[3] Occasionally, however, owing to a defective cap or to a defective charge in the cartridge, or other cause, the imprint is not fully developed and then is not characteristic. The general shape of the bottom of the depression, apart from details, sometimes is distinctive, but is liable to vary with the force with which the striker hits the cap, with the thickness of the metal of the cap and more particularly with the internal pressure, that is with the response of the metal envelope of the cap to the detonation that takes place within. The position of the depression on the cap whether for instance it is centrally situated or to one side, is usually, though not invariably, constant for any one weapon. Crossman [4] records a case in which the indentation made by the striker of a revolver, which was in a

[1] In the British military rifle cartridge this is usually about 0·6 of a grain and in the Service revolver cartridge 0·4 of a grain.

[2] This varies in composition with different manufacturers ; in British military rifle cartridges it consists of fulminate of mercury, chlorate of potassium, sulphide of antimony, sulphur and black powder. See J. S. Hatcher, *Textbook of Pistols and Revolvers*, pp. 283–285.

[3] See also J. S. Hatcher, *Textbook of Firearms Identification*, pp. 270–274.

[4] E. C. Crossman, *The American Journal of Police Science*, 1 (1930), pp. 321–2.

worn condition, differed in position according to whether the weapon was fired slowly or quickly. Gunther states [1] [2] that the lip sometimes found at one side of the top of the depression on a fired cap is due to the relatively slow action of the spring of the weapon in returning the firing pin to its normal position which causes the case to pivot on the end of the pin while this is still protruding through the breech block. A firing pin that is slightly too long or abnormally high pressure in the cartridge may produce the same result.[3]

The cap, too, generally is marked by the breech face or bolt head of the weapon.

The examination is best carried out by means of a comparison microscope with a magnification of about ten to twenty diameters and the case should be turned round and examined from all sides, so that the light may fall upon the interior of the cap indentation at different angles. If the cap is dirty, as it often is, a little of the dirt should be removed (without scraping, which would mark the cap) and its nature determined, after which the cap should be cleaned with a soft cloth damped with water or alcohol. Taking a cast of the indentation, which sometimes is recommended, is not of much use, except for photographic purposes (for which it often is convenient), as the finer details of the markings usually are not reproduced. A good material for taking a cast is celluloid, as recommended by Moritz.[4] In addition to any enlarged photographs of the cast of the striker depression, photomicrographs of this depression, although difficult to obtain, also should be taken. As already mentioned, in a recent murder trial [5] the connexion between an empty cartridge case found on the scene of the crime and the rifle of the accused person was proved from the presence in the impression on the cap of at least fourteen different marks that were identical with the marks on the striker of the rifle and in the case of the murder of Police Constable Gutteridge by Browne and Kennedy certain marks on the breech face of one of Browne's revolvers were reproduced on the cap of a fired cartridge case discovered in connexion with the crime.[6]

The table on page 210 shows the results of a critical examination of the striker impressions on the caps of 268 cartridge cases, from which it may be seen that a very large proportion of the caps examined (97·8 per cent.) were marked in a distinctive and characteristic manner. See also page 242.

Wads. The primary function of the wad is to provide a gastight seal

[1] C. O. Gunther, *Mechanical Engineering*, **52** (1930), p. 113.
[2] J. D. and C. O. Gunther, *The Identification of Firearms*, pp. 59, 60, 274.
[3] G. Burrard, *op. cit.*, p. 121.
[4] A. R. Moritz, *The Police Journal*, **11** (1938), pp. 364–369.
[5] G. W. Baker, " Scientific Evidence Relating to Firearms with Special Reference to a Recent Murder Trial," *Analyst*, **55** (1930), pp. 740–1.
[6] W. T. Shore, *Trial of F. G. Browne and W. H. Kennedy*, 1930, pp. 105–9 ; Figs. 1, 2, 3 (pp. 23, 24, 25).

as the projectile passes into the barrel, but when used with black powder it serves also to clean and lubricate the bore and in a shotgun cartridge it serves to separate the powder from the pellets or slugs.

In shotgun cartridges there are generally two varieties of wads, one felt wad, which may be greased, and three card wads one of which may be grease-proof to prevent the grease from the felt wad coming into contact with the powder, and these wads differ very much in different makes of cartridges. Thus the felt differs in colour and in thickness, and the card wads also differ in thickness, and may be faced with waxed paper, white glazed paper, black glazed paper or coloured paper, and the wad situated

STRIKER MARKS ON CAP

Weapon.[1]	No. of Caps Examined.	Marks.	
		C.[2]	N.C.[3]
A	20	19	1 [4]
B	20	15	5 [5]
C [6]	20	20	—
C [6]	20	20	—
D	20	20	—
E [7]	25	25	—
E [7]	25	25	—
F [8]	8	8	—
I	12	12	—
J	17	17	—
K	20	20	—
L	20	20	—
M	3	3	—
N	20	20	—
O [9]	13	13	—
S [10]	5	5	—
Total	268	262	6
	Per cent.	97·8	2·2

[1] For nature of weapon, see p. 223. See also p. 242.

[2] C. means characteristic.

[3] N.C. means non-characteristic.

[4] After re-examination it was decided that this one case, included previously with those characteristically marked, would be described better as non-characteristically marked.

[5] One cartridge had a defective charge, or no charge at all, and one a defective cap, which split; the explanation for the other three was not apparent.

[6] Same weapon, but different ammunition. These marks were particularly characteristic.

[7] Same weapon, but different barrels (shotgun). The empty cases were kindly supplied by a friend, who specially collected them after shooting.

[8] Self-loading pistol (Parabellum) 9 mm. Only the cases were examined, not the bullets.

[9] Three rounds were fired in England and the revolver, fired bullets and cases and some cartridges were then sent to me in Egypt, where I fired ten rounds. The original question at issue had nothing to do with the marks on the fired cartridge cases.

[10] Fired in England.

at the end of the cartridge immediately over the shot is covered generally with a paper label (often coloured) giving the description of the powder and the size of the shot. Even in the same make of cartridge the wads are not always uniform. Sometimes a composition is used in place of felt, or a white or grey cloth wad or combined cloth and card wad may be substituted for one of the card wads. Generally in British shotgun cartridges, both the card wad over the powder and that over the felt are one-twelfth of an inch thick and that over the shot one-sixteenth of an inch, though sometimes a card wad may be only one-twentieth of an inch. The thickness of the felt is adjusted to the amount of powder and shot and may vary from about a quarter to about half an inch.[1]

Frequently the card wad that comes into immediate contact with the shot bears indentations and marks made by the pellets, from which the number corresponding to the area of the wad, and hence their size, can be determined. Occasionally the paper label from the end of the cartridge, that bears the description of the powder and the size of the shot, is found intact. In the Monson case [2] two guns were involved, one a 12-bore and the other a 20-bore, and a great deal depended upon from which of the two guns the fatal shot had been fired and a blood-stained wad found near the body corresponded in size with those from the cartridges for the 12-bore gun. Certain cartridges loaded with slugs examined by me have contained two wads, one cardboard and the other fibre. In rifle, revolver and self-loading pistol cartridges there is never more than one wad and generally none, and when present it is often a glazed cardborad disc placed between the powder and the bullet. In several revolver cartridges examined there was a flat-topped cone-shaped wad of hard, brittle material that crumbled to dust when fired.

It is evident, therefore, that the nature, diameter [3] and thickness of any wads found in connexion with a shooting case may provide valuable evidence and wads always should be looked for, though as a rule they are present only where a shotgun has been employed. In out-of-the-way places where muzzle-loading weapons are still employed and home-made wads used, the remains of these from the scene of a crime sometimes may be identified as part of a fabric in the possession of a suspected person.[4]

Cartridge Cases (Shells). Fired cartridge cases found in connexion with a crime may be as important as bullets by reason of the markings on them, and often even more important especially if the bullet has been defaced by impact against bone or other hard substance, and, therefore,

[1] See also J. S. Hatcher, *Textbook of Firearms Identification*, pp. 218–222.
[2] J. W. More, *Trial of A. J. Monson*, 1908, p. 374.
[3] Tables showing the relation of the bore of a shotgun to the diameter of the wads in the cartridges made for that size of gun are published by various manufacturers.
[4] C. T. Symons, "Evidence from Gun-Wads," *The Police Journal*, 6 (1933), pp. 103–19.

always should be searched for and submitted to the expert. Thus from an empty cartridge case, not only may the nature and size of the projectile, the nature of the weapon and the kind of powder sometimes be ascertained, but also the identity of the particular weapon that fired the shot. This is revealed, as already explained, by the characteristic markings left on the case by the tool marks or any peculiarity or defect of the breech face or bolt head, by the extractor and by the ejector and by the markings on the cap (which forms an integral part of the cartridge case) made by the striker and by the breech face or bolt head.

The kind of case, the dimensions and all marks indicating the manufacturer, date or size, and in shotguns the nature of the powder (which sometimes is stated on the case), should be recorded. With fired cases from revolvers it is useful to ascertain from a chemical examination of the residue the kind of powder used, whether for instance it was black or smokeless. In the Browne and Kennedy murder both kinds of cartridges were employed,[1] which fact was of importance.

For the examination of the markings on the base of the case a comparison microscope [2] and a magnification of about 10 to 20 diameters is recommended, depending upon the size of the case, the larger the case the smaller the magnification required, and the case should be turned round and viewed from all sides so that the light may fall on the markings at different angles. Enlarged photographs or photomicrographs of the marks should be made for comparison purposes and for exhibition in Court. The extractor marks and any ejector marks not on the base of the case are examined best first by means of a good lens with a magnification of about ten diameters and then in greater detail, if possible with a comparison microscope or if this is not possible then with a binocular stereoscopic microscope. Photographs of these marks should be taken and enlarged.

The table (p. 213) shows the results of a critical examination of the marks on 268 cartridge cases made by the breech face or bolt head of various weapons and by the extractor and by the ejector, where these latter were present, from which it may be seen that a large proportion of the cases bore distinctive and characteristic marks.

In the case of self-loading pistols, the fired cartridge cases are ejected automatically, one by one, after each shot; with magazine rifles the fired case is ejected only when the bolt is drawn to allow a fresh cartridge to pass into the firing chamber; with revolvers, even of the ejector type, the fired

[1] W. T. Shore, *Trial of F. G. Browne and W. H. Kennedy*, 1930, pp. 105–9; Figs. 1, 2, 3 (pp. 23, 24, 25).

[2] The comparison microscope made by the Spencer Lens Company is provided with two iris-diaphragm holders for cartridge cases that will take cases of all sizes and that are simple and practical in use.

cases are not ejected until the breech is opened to insert fresh cartridges, which generally is not until the cartridges in all the chambers have been fired; with shotguns provided with an ejector, the cases are ejected only when the breech is opened. Shots, therefore, fired from a self-loading pistol must leave cases in the vicinity of the shooting and the fact that in any particular instance cases are not found generally points to the use of some other form of weapon, a revolver for example, though occasionally the cases may have been removed before any systematic search for them had been made. Shots from rifles, revolvers and shotguns may, or may not, leave empty cases, depending upon whether or not these have been ejected

MARKS ON FIRED CARTRIDGE CASES [1]

Weapon.[2]	No. of Cases Examined.	Breech Marks.		Extractor Marks.		Ejector Marks.	
		C.[3]	N.C.[4]	C.[3]	N.C.[4]	C.[3]	N.C.[4]
A . .	20	18	2 [5]	20	—	17	3 [5]
B . .	20	18	2 [6]	19	1 [7]	—	20 [7 11]
C [8] . .	20	20	—	—	—	—	—
C [8] . .	20	—	20	—	—	—	—
D . .	20	20	—	—	—	—	—
E [9] . .	25	25	—	—	—	—	—
E [9] . .	25	—	25	—	—	—	—
F [10] . .	8	—	8	4	4	8	—
I . .	12	12	—	12	—	12	—
J . .	17	17	—	—	—	—	—
K . .	20	20	—	20	—	19	1 [5]
L . .	20	20	—	20	—	20	—
M . .	3	3	—	—	3 [11]	—	3
N . .	20	20	—	—	20 [11]	—	20
O [12] . .	13	13	—	—	—	—	—
S [12] . .	5	5	—	—	—	—	—
Total	268	211	57	95	28	76	47
	Per cent.	78·7	21·3	77·2 [13]	22·8 [13]	61·8 [13]	38·2 [13]

[1] See also tabular statement on p. 242.
[2] For nature of weapon see, p. 223.
[3] C. means characteristic.
[4] N.C. means non-characteristic.
[5] The explanation is not apparent.
[6] One cartridge had a defective charge, or no charge at all; the explanation for the other was not apparent.
[7] One cartridge had a defective charge or no charge at all.
[8] Same weapon, but different ammunition.
[9] Same weapons, but different barrels (shotgun). See footnote No. 7 to previous table.
[10] See footnote No. 8 to previous table.
[11] After re-examination it was decided that, although these extractor and ejector marks were considered previously as characteristic, they would be described better as non-characteristic.
[12] See footnotes Nos. [9] and [10] to previous table.
[13] Revolvers and shotgun excluded from the total number on which percentage alculated.

deliberately or left in the weapon, or accidently dropped as in the Gutteridge murder.[1]

It should not be forgotten, however, that cartridges are not employed always with the particular kind or size of weapon for which they were designed. Thus a self-loading pistol cartridge may be fired from a revolver [2] and a revolver cartridge, if the projecting rim is removed, may be fired from a self-loading pistol.[3] A number of such cases have come under my notice. In one of these, self-loading pistol cartridges had been adapted for use in a revolver (for which in their normal condition they were too long and prevented the cylinder from revolving) by having had the bullets extracted, part of the charge withdrawn and the bullets then replaced. In another ease, a cartridge, also too long, had been shortened by having had the tip of the bullet cut off and in a third instance brass cases (probably stolen military rifle ammunition) had been shortened by filing and the original coated bullets had been replaced by lead bullets that had been filed, cut and hammered to make them fit. In this instance all identification marks had been filed from the cases. The special Nagant revolver ammunition may be instanced since it may be fired not only from the true Nagant revolver [4] and from revolvers of the Nagant type, but also from other revolvers of different kinds having different and varied rifling. A weapon, too, may be a composite one, for example one made from parts of others, thus about 1925 an American firearms manufacturer converted many thousands of ·38 self-loading well-known non-American pistols to take a ·32 cartridge by substituting for the original barrels others cut from ·30 calibre rifle barrels,[5] or a weapon may be an amateur-made one.[6]

In the Dickman murder case [7] four bullets were found, two being ·320 uncoated lead bullets and two ·250 nickel-coated self-loading pistol bullets, all of which probably had been fired from the same weapon, the smaller

[1] W. T. Shore, *op. cit.*, p. 18.

[2] Special clips have been made to take self-loading pistol cartridges for use in revolvers (*Textbook of Small Arms*, 1929, p. 90; C. Goddard, *American Journal of Police Science*, 1 (1930), pp. 63–4.

[3] See also J. S. Hatcher, *Firearms Investigation, Identification and Evidence*, pp. 244-5.

[4] The Nagant revolver, invented by the firm of Nagant Brothers of Liège, Belgium, in 1874, incorporates an ingenious system intended to prevent gas escape between the cylinder and the barrel, whereby, on firing, the cylinder moves forward and the breech end of the barrel, which is tapered (coned), enters the chamber opposite, the chambers being recessed for the purpose, thus making a gas-tight joint. Also the front end of the cartridge (which projects slightly beyond the revolver cylinder, the front end of the cartridge case extending beyond the nose of the bullet) enters the barrel and makes another gas-tight joint. Many cheap imitations of this revolver are made. The ammunition (3·8 cm. long) may be fired from any revolver of the requisite calibre (7·62 mm.) if the chambers in the cylinder are long enough to take it.

[5] C. H. Goddard, "The Identification of Projectiles in Criminal Cases," *The Military Surgeon*, 58 (1926), p. 144.

[6] N. Suskin, "Military Firearms adapted by Criminals to suit their Purposes," *The American Journal of Police Science*, 1 (1930), pp. 549–64.

[7] S. O. Rowan-Hamilton, *Trial of J. A. Dickman*, 1914, pp. 11, 89.

size bullets having been wrapped in paper to make them fit the barrel. A piece of paper that might have been used for this purpose was found on the scene of the crime, but its significance was not realized until after the trial, and the presence of two different kinds and sizes of bullets puzzled both judge and counsel.

The shape of the base of a cartridge case usually conforms to one of three types, namely, rimmed,[1] rimless [2] or semi-rimless.[3] Military rifle cartridges may be of any one of the three types, thus, of the cartridges of fourteen nations, five (including the British) have rims, eight are rimless and one semi-rimless; sporting rifle cartridges generally have rims, revolver and shotgun cartridges invariably have rims, and self-loading pistol cartridges are usually rimless, but may be semi-rimless, the rim, however, being very slight. Where there is no rim or only a slight one, the cartridge has a recess round the base for the extractor to engage in.

PROJECTILES

Projectiles for firearms comprise bullets, small shot and slugs, each of which may differ from others of the same kind, not only in size, shape and weight, but also in composition, particularly when made by different manufacturers or in different countries; hence in cases of murder, attempted murder or wounding by shooting, the examination and chemical analysis of the projectile may provide valuable evidence. The rifling marks and other marks, too, upon a bullet may indicate, not only the kind of firearm used, but even the specific weapon, and so may incriminate a particular person. The various kinds of projectiles may be described.

Bullets. The points requiring attention in any examination of a bullet are (*a*) adherent foreign material; (*b*) composition; (*c*) diameter; (*d*) weight and (*e*), most important of all, the rifling marks and other marks on the surface.

Adherent Material. This may be blood, tissue, hair or other fibre, or foreign matter of various kinds. If not strongly adherent and if likely to become detached during subsequent handling, it should be removed without scratching the bullet, its nature determined and the residue retained; if strongly adherent, it should be allowed to remain unless it obscures the marks, its nature, however, being ascertained, if possible. Blood and smoke often obscure the markings and usually after examination and noting they should be removed with soap and water, care being taken to avoid scratching the soft metal of lead bullets. Any wax or other lubricant in the cannelure

[1] In a rimmed cartridge the edge of the head is of a greater diameter than the cylindrical portion and projects well beyond it.

[2] In a rimless cartridge the edge (flange) is of the same diameter as the cylinder and therefore does not project beyond it.

[3] In a semi-rimless cartridge the edge (flange) is of slightly greater diameter than the cylinder and projects slightly beyond it.

should be examined and its nature determined, which usually may be done from its appearance and a few simple tests, such as that of the melting point. Unless this lubricant prevents a full examination of the markings on the bullet it should be allowed to remain.

Composition. Bullets generally are made either of lead sometimes very thinly plated with copper as in some American revolver bullets, or of lead enclosed in a thin envelope of some harder metal, usually cupro-nickel [1]; steel [2] sufficiently soft to take the rifling marks of the barrel, or sometimes a copper-zinc,[3] or other copper alloy,[4] a notable exception being the French military rifle bullet, which consists of an uncoated copper alloy.[5] The British military rifle bullet Mark VI consists of a lead core enclosed in a cupro-nickel envelope (80 per cent. copper and 20 per cent. nickel [6]); Mark VII bullet is of lead tipped with aluminium or an alloy of aluminium and zinc (aluminium 90 per cent. and zinc 10 per cent.), or fibre, or paper, enclosed in an envelope similar to that of Mark VI.[7] In America an envelope consisting of what is termed "gilding metal" (an alloy of 90 per cent. copper and 10 per cent. zinc) has been found to reduce fouling. Rifle bullets used for sporting purposes frequently are entirely of lead uncoated, but sometimes are partly coated (soft-nosed) the front portion being left bare; revolver bullets often are uncoated [8] but self-loading pistol bullets are always coated. Certain German rifle cartridges examined marked "40" (1940) had a bullet with a hard steel core coated with a copper alloy, as also had certain British machine-gun cartridges.

The lead employed for bullets, which is ordinary trade lead, usually contains small proportions of various impurities, among which are arsenic, antimony and tin. Antimony and tin also are added frequently for hardening purposes in order to give the bullets greater penetrating power, the lead core of the British military bullets Marks VI and VII for example being hardened by the addition of two per cent. of antimony [6] and the lead bullet of the British army ·455 revolver cartridge being hardened with tin (lead 12 parts, tin 1 part) or with one per cent. of antimony.[9]

For the determination of the exact composition of a bullet, a chemical analysis is necessary and the method employed will be described later. In

[1] Military rifle bullets of Great Britain, Belgium, Italy, Japan, Norway, Portugal, Roumania, Russia, U.S.A. (*Textbook of Small Arms*, 1929).
[2] Military rifle bullets of Austria, Germany, Greece, Holland, Hungary, Spain, Switzerland and Turkey. (*Textbook of Small Arms*, 1929.)
[3] This alloy was found coating bullets supplied in 1941 by the U.S.A. to the British army.
[4] The military rifle bullets of Denmark are coated with an alloy of steel, nickel and copper. (*Textbook of Small Arms.*)
[5] *Textbook of Small Arms.*
[6] War Office, *Musketry Regulations*, 1909, pp. 50, 51.
[7] *Musketry Regulations*, p. 51; *Textbook of Small Arms*, p. 210.
[8] During the recent war the British army ·380 and ·450 revolvers had coated bullets.
[9] War Office, *Textbook of Small Arms*, 1929, p. 263.

the case of a coated bullet, if a chemical analysis is required, the composition of both the core and the envelope should be determined, for which purpose they may be separated by melting the lead and pouring it out through the uncoated area at the base.

Dimensions. Both the diameter and the length of a bullet should be determined. The former depends upon and varies with the calibre of the weapon for which it was designed and, if intended for rifled arms, also with the depth of the rifling, since it is made large enough to fill the barrel almost to the bottom of the rifling grooves, into which the base is expanded [1] by the gas pressure and heat generated on firing, the diameter across the lands being decreased and that across the grooves increased, thus tending to prevent any leakage of gas, which, if serious, would reduce the efficiency of the weapon. Modern bullets for rifled arms, therefore, are made slightly larger than the bore of the weapon for which they are intended to be used, though very slightly less than the diameter across the grooves. The diameter of the British army ·303 rifle bullet may be as much as 0·009 inch more than that of the bore [2]; the ·455 Service revolver bullet may be 0·014 inch more than the bore [3]; the U.S.A. military automatic pistol, which has a nominal bore of ·45 and an actual bore of ·445 inch and a groove diameter of 0·451 inch, takes a bullet 0·45015 inch in diameter.[4] In an American murder trial it was stated in evidence that a nominal ·38 rifle bullet measured 0·40 inch.[5]

Weight. This may be an important factor in the identification of a bullet, especially if it has been distorted by impact against a hard surface. Bullets are of so many different weights that it would be impossible to enumerate them all; thus Burrard mentions [6] 56 different kinds of British sporting rifles, 52 of which take bullets of different weights, varying from 100 grains (6·5 grams) to 1,882 grains (122 grams); Pollard gives particulars of 32 different self-loading pistols many of which have bullets of different weights,[7] varying from 49 grains (3·2 grams) to 224 grains (14·5 grams); the armies of various nations use 16 different weights of rifle bullets, which range from 139 grains (9·3 grams) to 244 grains (15·8 grams).[8] Bullets of the same nominal weight differ slightly among themselves, since it is impossible to make them all precisely the same; thus one lot of rifle bullets (3) examined varied from 10·91 grams to 11·33 grams; another lot (12) of a different size varied from 13·89 grams to 14·08 grams; a lot of revolver bullets (5)

[1] Streamline, armour-piercing and tracing bullets are exceptions, as they are so hard that they do not expand (*Textbook of Small Arms*, p. 269).
[2] *Textbook of Small Arms*, p. 418.
[3] Anon., *Analyst*, **48** (1923), pp. 380–1.
[4] C. O. Gunther, *Mechanical Engineering*, **52** (1930), p. 108.
[5] H. Parker, *Trial of John C. Best*, Boston, 1903, pp. 569, 570, 582, 605.
[6] G. Burrard, *Notes on Sporting Rifles*, 1920.
[7] H. B. C. Pollard, *Automatic Pistols*, 1920.
[8] War Office, *Textbook of Small Arms*, 1929, pp. 418–20.

varied from 9·40 grams to 9·48 grams; another lot (7) of a different size varied from 17·15 grams to 17·31 grams; a lot of self-loading pistol bullets (3) varied from 5·55 grams to 5·71 grams and another lot (3) of a different size varied from 3·17 grams to 3·19 grams. A large number of weights will be found recorded in the catalogues of the various manufacturers, but any table of bullet weights to be of value for forensic purposes should show the maximum and minimum weights of bullets nominally the same.

Rifling and other Marks. Bullets sometimes are marked on the base by the manufacturer with letters or figures. All such marks should be noted, as they may be useful for identification purposes. The cannelure,[1] too, should be examined, and whether it is plain or knurled,[2] and the kind of knurling should be noted, as sometimes this may be helpful. In addition to the manufacturer's marks, however, all bullets fired from rifled arms bear on their cylindrical surface marks caused by the rifling. These may be termed primary marks and they take the form of grooves engraved by the lands of the barrel, and, therefore, they are not parallel to the long axis of the bullet, but are slightly inclined to the right or left, according to whether the twist of the rifling is in the direction of the hands of a clock or the reverse. The number of grooves, their direction, angle of pitch, width and the distance between them should be determined.[3] These grooves indicate merely the type of weapon and not the particular weapon employed.

A frequent feature of the grooves made on a bullet by the lands of the barrel through which it has been fired is what has been termed variously " a second set of grooves "; a " doubling of the grooves "; a " slippage "; a " tippage " and a " skid mark," which may best be described by explaining the manner in which it is caused. For a number of reasons (because the chamber of a revolver may not be absolutely in a straight line with the barrel at the moment of firing, because in revolvers there is a short space between the chambers and the barrel, which the bullet must jump before it can enter the barrel [4] and because in self-loading pistols the cartridge may fit loosely in the chamber) the bullet does not always enter the barrel absolutely straight, but often is slightly inclined, with the result that it is marked first by the edges of the lands at the breech end of the barrel while in this inclined position, after which it is forced into its normal straight path and again marked. Thus there is a duplication of the grooves, sometimes only at the top, but sometimes most of the way down, the two sets of grooves being inclined at an angle to one another, the general appearance

[1] Groove round the bullet, of which there may be one, two, or three.
[2] Corrugated, ridged.
[3] The depth of the grooves on a bullet is not of much value, since there is no certainty that the lands of the bullet have bottomed the grooves in the barrel, and often they do not.
[4] The Nagant revolver (see p. 214) is an exception.

being a normal set of grooves with splayed tops. This false grooving, although most common on revolver bullets, may be present also on bullets from self-loading pistols and on bullets from the Thompson submachine gun [1]: it is, however, not always present on all the bullets from the same weapon, nor even always on all the grooves of the same bullet.

In addition to the primary marks there are on all bullets also a large number of accidental or secondary marks, of which some few (*a*) may be caused by occasional gross irregularities or imperfections in the barrel (often near the muzzle end), of the nature of those already described (*e.g.* pronounced peculiarities of the rifling or defects due to accident, bad workmanship or other cause), which when they occur are so plain that they constitute evidence that cannot be disputed and hence their individuality and significance are generally admitted. Other secondary marks are (*b*) longitudinal striations on the lands and (*c*) longitudinal striations in the grooves.[2] Although there are many references in the literature of the subject to marks (*b*) and (*c*) and their importance, frequently no distinction is made between them and sometimes land markings and groove markings are mentioned without any clear statement whether they refer to the barrels or to the bullets, and differences of opinion exist among experts respecting their value.

Gunther states that, generally, marks (*c*) which, however, he calls " land impressions " though from the context it is clear that impressions from the lands of the barrel and not impressions on the lands of the bullets are meant, furnish more reliable evidence than marks (*b*).[3] Hatcher also seems to rely upon marks (*c*).[4] Perry accepts marks (*b*) as " very characteristic and capable of proving direct association with a particular weapon." [5] Goddard [6] [7] [8] [9] accepts both marks (*b*) and (*c*) as significant, but seems to place greater value upon (*b*) [8] and illustrates his articles on the subject by

[1] Colonel Calvin Goddard (" The Valentine Day Massacre," *The American Journal of Police Science*, Vol. 1 (1930), p. 73) says this is not present on bullets from the Thompson machine gun, but the only bullets I have examined from this gun which were five in number, all showed this mark. The gun was stamped " Thompson submachine gun, calibre ·45 automatic cartridge Model of 1928," and the cartridges were of American manufacture.

[2] The striations on the envelope of a coated bullet due to the " drawing " of the metal are not included.

[3] J. D. and C. O. Gunther, *The Identification of Firearms*, pp. 96, 237.

[4] J. S. Hatcher, (*a*) *Army Ordnance*, **14** (1933), p. 95; (*b*) *Textbook of Firearms Identification*, p. 276.

[5] G. H. Perry, *Analyst*, **55** (1930), p. 743.

[6] C. H. Goddard, " Scientific Examination of Firearms and Bullets," *Journal of Criminal Law and Criminology*, **17** (1926), pp. 258, 261.

[7] C. H. Goddard, " Forensic Ballistics," *Army Ordnance*, **6** (1925), pp. 198–9; Figs. 4, 5.

[8] C. H. Goddard, " Who Did the Shooting? " *Popular Science Monthly*, Nov., 1927, p. 22.

[9] C. H. Goddard, " The Identification of Projectiles in Criminal Cases," *The Military Surgeon*, **58** (1926), pp. 153–4.

photographs of (*b*).[1] [2] [3] Pollard [4] rejects both (*b*) and (*c*) and states that "No reliance can be placed on these *striæ*, French and American experts notwithstanding." He attributes them as "almost certainly due to metallic fouling from the fore-part of the projectile rolling up between the barrel surface and the bullet" and states that they are variable and not permanent characteristics and "may alter in incidence or position with every shot or remain fixed for a few shots and then change."

In view of this difference of opinion it becomes necessary to consider the matter in detail and to endeavour, if possible, to discover the causes producing marks (*b*) and (*c*), for only by so doing can their value or non-value be ascertained and to distinguish, if possible, between fluctuating marks and those made by permanent features of the barrel, which may be done to some extent from theoretical considerations, but more satisfactorily by firing a number of shots through the same barrel and carefully analysing the results and noting the marks that are recurrent.

Unquestionably some of the secondary marks are entirely fortuitous and a small proportion (made during manufacture and in loading the bullet into the cartridge case) may even exist before the firing, though hidden from view by the case. Naturally, however, only the markings made during the passage of the bullet through the barrel need be considered and some of these may be of little or no evidential value in forensic cases, the factors producing them being variable.

The want of clearness existing in the literature of the subject when the striations on bullets are referred to, as to whether they are on the lands or in the grooves, has been mentioned. For any scientific or useful discussion of the striations this information is essential, and particularly so when the causes are being considered. When these causes are particularized a similar lack of scientific precision is often found, the striations being attributed frequently, either specifically or by inference, without any qualifications, to tool marks in the barrels of the weapons. Thus the methods of drilling, reaming and rifling barrels respectively are described, and it is explained how the reaming and rifling tools leave marks in the barrels, which is all quite true, but it is not the whole truth, and it is often stressed too much, and either it is not mentioned at all, or it is not made sufficiently clear, (*a*) that modern reaming and rifling tools are often so efficient that the marks left are so fine they can be seen only when magnified; (*b*) that in barrels that have been finished by lapping the tool marks largely

[1] C. H. Goddard, "Forensic Ballistics," *Army Ordnance*, 6 (1925), pp. 198–9; Figs. 4, 5

[2] C. H. Goddard, "Who Did the Shooting?" *Popular Science Monthly*, Nov., 1927, p. 22.

[3] C. H. Goddard, "The Identification of Projectiles in Criminal Cases," *The Military Surgeon*, 58 (1926), pp. 153–4.

[4] H. Pollard, "What the Bullet Tells," *Discovery*, 5 (1924), p. 281.

are obliterated by the lapping and fresh marks due to the abrasive powder used are produced ; (*c*) that at an early stage in the life of a barrel the tool marks become effaced by erosion or by other marks caused by rust, cleaning, grit, and particularly by particles of metal from the bullets, and (*d*) that in practice a firearm employed to commit a crime is seldom new, but often one that has been much used and badly treated, and hence one in which the original tool marks in the barrel have disappeared entirely. As Burrard has shown,[1] the firing of fifty rounds in the case of lead bullets and twenty-five rounds in the case of coated bullets may be sufficient to change completely the finer striations in the barrel of the weapon used. There are also other considerations to be taken into account. Thus, since any marks in the barrel of a weapon, if they affect the bullet at all, will produce corresponding marks, it follows that the ordinary tool marks, being fine [2] (*i.e.* shallow and narrow), cannot produce the comparatively coarse (*i.e.* deep and wide) scoring so often present on bullets, which in some instances is as deep as the rifling grooves ; it follows also that the tool marks in the grooves of a barrel, being longitudinal, can produce only longitudinal striations on the lands of a bullet and that the circumferential tool marks on the lands of a barrel cannot ordinarily produce longitudinal markings in the grooves of a bullet, unless the edges of these tool marks are rough, in which case the roughness may take the form of tiny projections that may cause longitudinal striations on the bullet. The polishing, however, to which the barrels of weapons that have been finished by lapping are subjected usually will remove any such projections, and hence, in a weapon that has been lapped, there should not be any marks or projections on the lands to produce longitudinal striations in the rifling grooves of a bullet and, therefore, some other cause for such striations, that certainly occur on most bullets, must be looked for. One likely cause, to which no reference can be found, is the narrow band of marks near the muzzle end of the barrel, which is produced during the finishing process.[3] Other causes may be marks in the barrel due to rust, grit or metallic particles or to these factors acting directly on the bullets.[4] Whatever the metal of a bullet fired from a rifled arm may be, strips of it must of necessity be cut off by the lands of the barrel when making the grooves,[5] especially at

[1] See p. 198.

[2] In barrels that have been well finished the tool marks can only be seen if specially illuminated and magnified.

[3] See p. 194.

[4] As already pointed out, an important distinction exists between rust, grit and metallic particles in a barrel, which are temporary and variable, and the marks made on the barrel surface by these same factors, which marks are permanent and remain after the agents causing them have been removed.

[5] Modern bullets for rifled arms are not simply expanded into the rifling grooves of the barrel by the heat and pressure produced on firing, but being made slightly larger than the bore diameter (see p. 217) they must be and are, engraved by the edges of the lands at the breech end of the barrel.

the breech end where the bullet first comes in contact with the lands, and these metal particles, that are produced in every barrel with every shot and some of which often may be seen on the bullet partly attached to the edges of the grooves, must be present between the barrel surface and the bullet, on both of which and particularly on the latter manifestly they are likely to produce scoring.

In any consideration of bullet markings it should be remembered that a bullet is a comparatively small object passing rapidly through the barrel, with which it may, or may not, be in complete and continuous contact at every point and that the imprints it receives are not similar to those on a cast of the interior of the barrel, but are a composite of those produced by the permanent features and imperfections throughout the whole length of the barrel, together with those caused by any particles of grit or metal that may occur between the barrel surface and the bullet, and it is at the muzzle end of the barrel that a bullet receives its final and most important marking and it is there particularly that previous marks may be altered or obliterated.

It should be remembered too that if marks are made on a bullet at the very beginning of its passage through the barrel, when for a very short distance and for a very brief time, before it engages with the rifling, it is travelling with only a direct forward movement, they will be in the direction of the long axis of the bullet, but when the bullet is fully rotating in the barrel, they will be in the direction of the rifling. As a corollary to this, it follows that any striations on a bullet in the direction of the long axis must have been made at the extreme breech end of the barrel and that those parallel to the rifling cannot have been made at this point.

At this stage the results of the examination of the marks on 222 bullets, 192 of which have been specially fired for the purpose,[1] may be given and are shown in the tables on pages 223 and 224.

The bullets from weapons A to N inclusive were examined originally both with a binocular stereoscopic microscope (Zeiss) and with a comparison microscope (Watson and Sons). For the purpose of the third edition, the bullets mentioned were all re-examined with a comparison microscope made by the Spencer Lens Company of the U.S.A. and fitted with their latest improvements and accessories. Bullets O, P, R and S were also examined with this microscope.

From the first table the following facts may be seen, namely:

That of the 1,349 possible rifling grooves all were present, though a very small proportion (34 or 2·5 per cent.) were incomplete.

[1] The bullets except those from weapons O and S about the conditions of firing of which no particulars are known were fired into cotton and retrieved one by one as fired and numbered as retrieved, the barrel being cleaned after each shot.

Marks on Bullets

Order in which Bullets Fired.	Number of Incomplete Rifling Grooves.[1] Weapon.						Number of Lands Marked.[2] Weapon.															
	A	C[3]	C[3]	G2[4]	G3[4]	L	A	B	C[3]	C[3]	D	G1[4]	G2[4]	G3[4]	I	J	K	L	M	N	O[4]	P[4]	R[4]	S[4]
1	–	–	1	1	1	–	3	6	6	2	7	3	0	1	6	5	6	6	5	5	5	6	5	4
2	–	2	1	–	1	–	4	6	3	3	7	1	0	1	6	5	6	6	5	5	5	6	5	4
3	–	–	–	–	–	2	6	6	6	1	7	–	0	1	6	5	6	6	5	5	5	6	5	4
4	–	–	–	–	–	–	5	6	6	4	7	–	–	2	6	5	6	6	–	5	–	6	5	–
5	1	–	–	–	–	–	3	6	5	4	7	–	–	2	6	5	6	6	–	5	–	6	–	–
6	–	–	1	–	–	–	2	6	6	2	7	–	–	–	6	5	6	6	–	5	–	6	–	–
7	1	–	–	–	–	1	2	6	4	2	7	–	–	–	6	5	6	6	–	5	–	6	–	–
8	1	1	–	–	–	–	3	6	7	1	7	–	–	–	6	5	6	6	–	5	–	6	–	–
9	–	–	1	–	–	–	4	6	6	1	7	–	–	–	6	5	6	6	–	5	–	6	–	–
10	–	–	–	–	–	–	2	0[5]	6	1	7	–	–	–	6	5	6	6	–	5	–	6	–	–
11	–	–	–	–	–	–	2	6	4	1	7	–	–	–	6	5	6	6	–	5	–	–	–	–
12	–	–	–	–	–	–	2	6	4	0	7	–	–	–	6	5	6	6	–	5	–	–	–	–
13	1	–	–	–	–	1	3	6	4	1	7		–	–	–	5	6	6	–	5	–	–	–	–
14	1	–	1	–	–	–	3	6	7	1	7	–	–	–	–	5	6	6	–	5	–	–	–	–
15	1	–	–	–	–	–	5	6	7	0	7	–	–	–	–	5	6	6	–	5	–	–	–	–
16	–	–	–	–	–	2	2	6	7	1	7	–	–	–	–	5	6	6	–	5	–	–	–	–
17	1	–	–	–	–	2	2	6	4	2	7	–	–	–	–	5	6	6	–	5	–	–	–	–
18	1	–	–	–	–	2	2	6	5	1	7	–	–	–	–	–	6	6	–	5	–	–	–	–
19	–	–	–	–	–	–	6[6]	6	6	1	7	–	–	–	–	–	6	6	–	5	–	–	–	–
20	1	–	2	–	–	2	2	6	6	0	7	–	–	–	–	–	5	6	–	5	–	–	–	–
Grooves Twist							6 R	6 R	7 R	7 R	7 R	7 R	7 R	7 R	6 R	5 R	6 R	6 R	5 L	5 L	5 R	6 R	5 L	4 R

Nature of Weapon and of Ammunition

A. Self-loading pistol (F.N. Belgium), ·32 inch; barrel new; ammunition assorted: bullets coated.
B. Self-loading pistol (Webley and Scott), ·32 inch; barrel worn and rust-pitted; ammunition assorted: bullets coated.
C. Revolver (Webley and Scott), ·38; barrel new; ammunition alike for each 20 rounds, but the two lots differ, the first lot having naked lead bullets and the second coated tops and lead bases.
D. Revolver (Webley and Scott), ·455; barrel new; ammunition alike: bullets naked lead.
G1. Revolver (Webley-Fosbery), ·455; ammunition probably alike: bullets naked lead.
G2. Revolver (Webley and Scott), ·455; ammunition probably alike: bullets naked lead.
G3. Revolver, ·455; ammunition probably alike: bullets naked lead.
I. Self-loading pistol (Belgian), 6·35 mm.; barrel new; distorts after firing 6 rounds; ammunition assorted: bullets coated.
J. Revolver (Couet, French), 8 mm.; barrel new; rough machining; ammunition alike: bullets coated.
K. Self-loading pistol (Walther, German), 6·35 mm.; barrel new; ammunition assorted: bullets coated.
L. Self-loading pistol (Star), 7·65 mm.; barrel old; ammunition alike: bullets coated.
M. Rifle (Lee-Enfield), ·303; ammunition alike: bullets coated.
N. Rifle (Lee-Enfield), ·303; ammunition assorted: bullets coated.
O. Revolver (Turkish), 7·62 mm.; barrel old; ammunition alike; bullets (Nagant) coated.
P. Automatic pistol (Mauser, which was fully automatic), 7·65 mm.; barrel new; ammunition assorted; bullets coated.
R. Revolver, 7·62 mm.; barrel worn and rust-pitted; ammunition alike: bullets coated.
S. Revolver (Russian Nagant), 7·62 mm.; ammunition alike; bullets (Nagant) coated. Although five cartridge cases were examined (pp. 210, 213) only three bullets were available, two having been required for another purpose before any detailed examination could be made.

[1] On the bullets from weapons B, D, G, I, J, K, M, N, O, P and S all the rifling grooves were complete: the bullets from weapon R were so covered with marks that no rifling grooves could be seen, and even in the weapon itself neither separate lands nor grooves could be distinguished.

[2] In many instances the marks were very small; doubtful but possible traces were excluded.

[3] Same weapon, but different ammunition.

[4] Order of shots not noted.

[5] The cartridge had a defective charge and apparently there was no powder the bullet having been driven by the detonation of the cap composition.

[6] Bullet different from other nineteen.

MARKS ON BULLETS [1]

Weapon [2]	No. of Bullets Examined.	Characteristic and Recurrent Secondary Marks.	
		On Lands.	In Rifling Grooves.
A	20	None found	None found.
B	20	Two adjoining groups of *striæ* on 10 bullets [3]	
C [12]	20	(*a*) Two deep scratches on 4 bullets [4] (*b*) Shallow furrow with *striæ* on 3 bullets [5]	
C [12]	20	Shallow furrow with *striæ* on 4 bullets [6]	
D	20	(*a*) Shallow narrow furrow with *striæ* on all bullets (*b*) Narrow scratch on all bullets	(*a*) *Striæ* in 2 corresponding grooves of all bullets agree. (*b*) *Striæ* in 1 corresponding groove of a few bullets agree.
G_1	2	Shallow narrow furrow with *striæ* on both bullets	None found.
G_2	3	None found	
G_3	5	Shallow narrow furrow with *striæ* on all bullets	(*a*) *Striæ* in 1 corresponding groove of 3 bullets agree.[9] (*b*) *Striæ* in another corresponding groove of 4 bullets agree.[9]
I	12	Two deep furrows with *striæ* between on all bullets	(*a*) *Striæ* in 2 corresponding grooves of all bullets agree. (*b*) *Striæ* in 1 corresponding groove of a few bullets agree.
J [13]	17	(*a*) Several adjoining groups of *striæ* on all bullets (*b*) Similar curved lines on 6 bullets [7]	*Striæ* in what is probably a groove of 5 bullets agree.[10]
K	20	Two groups of *striæ* on 9 bullets [8]	Deep furrow in 1 corresponding groove of 4 bullets agrees.[11]
L	20	None found	None found.
M	3		
N	20		
O	3	A group of 6 *striæ* on 2 bullets [9]	
P	10	A group of 3 furrows on 3 bullets [9]	
R [13]	4	None found	
S	3		
Total	222		

[1] See also tabular statement on p. 241.
[2] See footnote to preceding table.
[3] Nos. 2, 3, 7, 8, 14, 15, 16, 17, 18, 20.
[4] Nos. 15, 16, 17, 18.
[5] Nos. 12, 13, 19.
[6] Nos. 2, 6, 9, 11.
[7] Nos. 1, 2, 4, 10, 13, 14.
[8] Nos. 1, 2, 3, 4, 9, 10, 12, 14, 19.
[9] Order of shots not noted.
[10] Nos. 4, 8, 12, 13, 14.
[11] Nos. 1, 2, 3, 4.
[12] Same weapon but different ammunition.
[13] The whole cylindrical surface of the bullets was so covered with marks that it was impossible to distinguish the lands from the rifling grooves or even to ascertain the number of grooves which could be done only by reference to the weapon.

That on the same bullets only 1,084 lands out of 1,349 (80·4 per cent.) were marked, 265 (19·6 per cent.) being unmarked.

Hence the major permanent features (the rifling) of the barrels of the weapons marked the bullets every time, whereas the minor permanent features such as the fine striations in the rifling grooves, if any of the marks were due to them, failed to affect the bullets in a large proportion of cases (19·6 per cent.).

That in five series of shots out of eighteen the number of lands marked varied on different bullets of the same series and this variation did not occur in any definite order or sequence. In the case of the two series of shots fired from weapon C, the different results were due almost certainly to the use of different ammunition, but this does not account for the differences among the bullets of the same series, nor does it account entirely for the differences among the bullets from weapon A, in which case, although the ammunition was assorted, there were many cartridges alike.[1] With weapons B,[2] I,[3] N [4] and P [5] the converse was the case, and although the ammunition was assorted, the number of lands marked was the same on each bullet of the same series.[6] It is of course well known that bullets nominally alike often vary slightly in size and shape and thus may fit the barrel more or less closely in some instances than in others and therefore may not always be marked alike.

From the second table the following facts emerge, namely :

That in only five series of shots out of eighteen (27·8 per cent.) could any characteristic secondary marks on the lands be found that recurred on every bullet of the series, and in two of these series the total number of shots was very small.

That in a further six series, although charactieristic marks occurred on the lands of some of the bullets, these were not present in every instance and, even when present, the bullets usually were not consecutive in order of firing.

In a previous edition of this book it was stated that not in any instance could characteristic and recurrent secondary marks be found in the rifling grooves of the bullets, but it was explained that this did not mean that such marks had been proved to be absent, but merely that they had not been found, although careful search had been made. As the number of bullets examined was 202, having a total of 1,242 rifling grooves, the examination was by no means an easy matter and, since it was not carried out under

[1] 11 cartridges were of one kind, 8 of another and 1 of another.
[2] 11 cartridges of one kind, 6 of another, 2 of another and 1 of another.
[3] 10 cartridges of one kind and 2 of another.
[4] 17 cartridges of one kind and 3 of another.
[5] In the case of P the number of each kind of cartridge was not noted.
[6] In the case of K, 16 cartridges were of one kind, 3 of another, and 1 of another : only one land of one bullet was unmarked.

the best conditions, but with a borrowed microscope and in unfamiliar surroundings, it was felt that it would be more satisfactory to re-examine these bullets,[1] for which purpose a new microscope was obtained having all the latest improvements and accessories, the bullet holders with their various movements, especially the fine adjustments for focussing each bullet separately and the lamps for illumination, being particularly satisfactory.[2] It was not surprising, therefore, that in a few instances agreement between the *striæ* in corresponding rifling grooves of bullets of the same series should have been found. These agreements, however, were not very characteristic and it was only after much consideration that they have been included in the tabular statement under the general heading of " characteristic and recurrent secondary marks." In no case was there agreement between the *striæ* in all, or even in the greater proportion, of the corresponding grooves of the bullets of the same series and the kind of agreement that existed, although it might be useful confirmation of other facts, was not sufficient by itself to prove identity of weapon. Thus, on the bullets from weapon D the agreement on all the bullets was only between the *striæ* in two grooves out of seven, both grooves being on the same side of the bullets, and on the bullets from weapon I the agreement on all the bullets was in two adjoining grooves out of six and in both instances the agreement consisted, not in complete identity of all the *striæ* in the corresponding grooves, but in a general likeness, varying from weak to strong, with a matching of a few of the more prominent *striæ*. Complete identity between all the *striæ* in any one rifling groove of one bullet and all the *striæ* in the corresponding rifling groove of another bullet probably never occurs. Burrard states [3] that " it cannot be considered safe to match two bullets unless coincidence of striations can be established on at least three different sides of both bullets " and Churchill says [4] that he " wants three grooves to match completely." In the other cases of agreement between the *striæ* in the corresponding rifling grooves of certain bullets of the same series (weapons D (*b*); G_3 (*a*) and (*b*); I (*b*); J and K) this agreement was in one or two grooves on only a small number of bullets and also was merely a general likeness and not identity.

In those instances where it is stated that no agreement has been found, this does not mean that in no case did one single striation on one bullet agree with any single striation in the corresponding rifling groove of another bullet, but that there was not sufficient agreement between the whole group of *striæ* in the corresponding grooves of different bullets of the same series to be characteristic. One point of considerable importance in this connexion,

[1] Twenty additional bullets were also examined. [2] See p. 222.

[3] G. Burrard, *The Identification of Firearms and Forensic Ballistics*, p. 161.

[4] R. Churchill, " Examination of Fire-Arms and Ammunition," *Trans. Medico-Legal Society*, **25** (1930–31), p. 98.

a point to which no reference can be found in the literature of the subject, is that whenever one set of fine lines close together is compared with another set of similar lines there is always agreement between some of the lines, although there may not be any connexion whatever between them. This may be demonstrated by drawing on paper (either with a ruler or by hand) with a fine pen and ink a series of fifty lines close together and immediately under and parallel to one another, care being taken to avoid as much as possible making the lines the same distance apart, then drawing a second set of similar lines on another sheet of paper, dividing each set into two by a straight cut across the middle and placing the left-hand half of one set against the right-hand half of the other set, when it will be seen that some of the lines of the two sets will correspond exactly, agreements varying from twelve per cent. to twenty-two per cent. having been obtained in various experiments made.

In order to show that a specific firearm sometimes may be identified as having fired a particular bullet, two experiments may be quoted. In one experiment Burrard [1] obtained from a manufacturer four *new* ·38 revolvers, which had been fitted specially with barrels that had been rifled consecutively on the same machine with the same cutter, but which were *not polished*: he fired five bullets from each of these revolvers and " was able in each case to match all the bullets fired from each individual barrel." In another experiment Goddard was able to determine which of six bullets fired specially, one from each of six *new* self-loading pistols, had been through which particular barrel, even though the six barrels had been made and rifled as three long barrels, each of which was subsequently cut into two, making three twin pairs.[2] Sometimes, however, exaggerated claims are made respecting " gun prints " on bullets. Thus one expert states that " . . . every weapon in the world leaves its individual tell-tale fingerprints on every bullet and shell it fires " [3]; again, " . . . each barrel leaves upon every bullet that passes through it a fingerprint that is peculiar to it and to it alone—just as characteristic, and just as useful for purposes of identification as the print left by the human finger," [4] and further, " These minute elevations and depressions are, of course, reproduced . . . on the surface of every bullet passing over them." [5] " Having found two matched grooves or lands both bullets may then be revolved simultaneously when the striations on every land and groove will be seen to flow into one another all around the circumference of each." [5] Another expert [6] says that

[1] G. Burrard, *op. cit.*, pp. 161, 163.
[2] J. S. Hatcher, *Army Ordnance*, **14** (1933), p. 95. See, however, J. D. Gunther and C. O. Gunther, *The Identification of Firearms*, pp. 52, 53, 276.
[3] C. H. Goddard, *Popular Science Monthly*, 1927, p. 22.
[4] C. H. Goddard, *Army Ordnance*, **6** (1925), p. 199.
[5] C. H. Goddard, *The Military Surgeon*, **58** (1926), pp. 153–4.
[6] R. Churchill, *Trans. Medico-Legal Society*, **25**, 1930–31, p. 86.

" Whatever characteristic the set of grooves in a fire-arm may possess they are imprinted upon the bullet." A third expert states,[1] respecting the examination of two bullets under the comparison microscope, that " If the bullets both came from the same gun there will be one point in this process where the pattern of lines will blend from one bullet into the other, the same as if it were a single bullet under view." That the interior of every barrel of a rifled arm possesses individual features that are peculiar to that barrel and to that barrel alone is not disputed, but every feature of a barrel is not necessarily imprinted on every bullet fired through that barrel, for example, as may be seen from the tabular statement previously given,[2] with one of the bullets fired from weapon B, with three bullets from weapon C and with three bullets from weapon G_2 all the lands were free from marks, although there were the usual striations in the rifling grooves of the respective weapons. Manifestly these particular bullets had not bottomed the rifling grooves in the barrels, the reason in one instance being that the cartridge had a defective charge ; in the other instances the causes were not apparent ; possibly, however, the bullets were small and fitted loosely into the barrel. In many other instances, as may be seen from the same tabular statement, some only of the lands were marked. In the case of fingerprints it is well known that certain prints, for instance, those made on rough surfaces, may be and generally are valueless for identification purposes.

J. D. and C. O. Gunther state[3] that " When consideration is given to the condition of evidence bullets generally it is doubtful whether the most skilled investigator will be able to reach definite conclusions in more than six out of ten cases," which means that in only sixty per cent. of the cases investigated can a definite positive recognition of a firearm be made from the marks on the evidence bullet.

In my opinion, sixty per cent. is too high a figure, especially since the evidence bullet may be so badly defaced that there are not any characteristic markings. In my experience, British army weapons (rifles, revolvers and self-loading pistols) are more difficult to identify than non-army ones, partly because they are much more used and cleaned than non-army ones, in consequence of which the bore becomes slightly enlarged, and the bullets, not fitting tightly into the barrel, are less marked, and partly because the army weapons being cleaned more often and, as a rule, more carefully than non-army ones, accidental marking of the barrel by rust, or by scratching from careless cleaning occurs less frequently, and, hence, there are fewer characteristic secondary marks in the barrel, and consequently the bullets are less marked.

[1] J. S. Hatcher, *Army Ordnance*, **14** (1933), p. 95. See, however, J. D. Gunther nd C. O. Gunther, *The Identification of Firearms*, pp. 52, 53, 276.
[2] See p. 223.
[3] J. D. and C. O. Gunther, *The Identification of Firearms*, 1935, p. 94.

The percentage of characteristic secondary marks calculated from the tabular statement on p. 224 is forty-one, whereas that given on p. 240 is forty-eight and a half. This latter figure, however, is too high, since it includes several examples in which the positive result was not the identification of a particular weapon, but only the identification of the type of weapon, which was all that was required in these cases, as for instance, whether the weapon was a British ·303 rifle, or an American Springfield ·3 rifle, or the type of revolver or self-loading pistol. The tabular statement on p. 241, which is a truer picture, shows a percentage of positive results of thirty-six and a half. The cartridge case evidence, on the other hand, was positive in more than ninety per cent. of the instances (pp. 210, 242).

It has not been possible to determine whether the characteristic marks that occurred on all the bullets of certain series were secondary marks of class (*a*), (*b*) or (*c*), though almost certainly in the case of the bullets fired from weapon J some at least of the marks were class (*a*). It is manifest, however, that marks on bullets that were deep cannot have been caused by the *ordinary* tool marks in the barrels, since these were always very shallow, and where deep marks occurred on all the bullets of a series it seems probable that they belonged to class (*a*) and were due to some permanent imperfection in the barrel, possibly deep scoring caused by metallic particles from coated bullets, rust or grit, and where they were present only on a proportion of the bullets of a series they were class (*b*) or (*c*) and were probably caused directly by metallic particles cut from the bullets, either fused to the barrel surface or loose between the barrel surface and the bullet. When the bullets marked were not consecutive in the order of firing, but the marks appeared, disappeared and re-appeared, this was due probably to the non-marked bullets fitting more loosely into the barrel than the marked ones and not making contact where the cause of the marking (which apparently must have been a permanent feature of the barrel) occurred.

Putting together the results given in the two tables and in view of the theoretical considerations already discussed, it may be seen that there is considerable evidence that a large proportion of the secondary marks on the bullets, both those on the lands and those in the grooves, were not due to permanent features of the barrels of the weapons used and, therefore, presumably they were due to temporary and variable factors, the most likely being particles of metal cut from the bullets by the lands of the barrels. This does not mean, however, that they are necessarily useless for identification purposes since when the markings on two or more bullets are identical, whatever may have caused them it was something in the same barrel and hence the bullets must have been fired from the same weapon.

In addition to the markings on bullets described, it is possible sometimes to see on the tip of a lead bullet the imprint of the texture of the cloth first penetrated. In order to identify this, an enlarged photograph is taken of the imprint and of comparison imprints made by firing bullets of the same kind and size through the suspected clothing.

Method of Examination. An inspection of the markings on a bullet with a good lens, giving a magnification of about 10 diameters, is a useful preliminary to the more detailed examination. It is also helpful to have a flat impression of the cylindrical surface, which may be obtained by rolling the bullet carefully and firmly along (*a*) dentist's moulding composition, the surface of which has been smoothed against a glass plate (this composition is used hot and sets hard when cold); (*b*) plasticine; (*c*) thick lead foil, such as is used in assaying gold [1]; (*d*) smoked paper as employed on the drums of recording apparatus in physiological laboratories [2]; or (*e*) cellulose acetate, or celluloid, supported on thin sheet celluloid and clipped round the bullet, as described by Moritz.[3] In my experience a five per cent. solution of celluloid (5 grams transparent, colourless celluloid cut into very small pieces, dissolved in 50 c.c. acetone and then 50 c.c. amyl acetate added and the whole well mixed) gives the best results, and in place of sheet celluloid (0·1 mm. thick) as the support, a thinner sheet of transparent, colourless cellophane (even as thin as 0·02 mm.), such as is used for wrapping up food and other materials, may be employed advantageously.

There is considerable difficulty in spreading the solution of cellulose acetate, or of celluloid, on the supporting base uniformly and free from streaks and air bubbles. Also, it is not easy to obtain and keep the necessary complete contact between the coated celluloid or cellophane and the bullet while this is being rolled and inserted into the clip.

If the supporting material is too thick, or if it is left too long before being removed from the bullet and before being mounted between the microscope slides, it curls up as it hardens and becomes useless. This does not happen with thin cellophane.

The results are valuable, especially when photographed and enlarged, but only when the possible imperfections and shortcomings of the method are fully realized. Thus, the possibility of streaks and air bubbles being mistaken for markings on the bullet is a very real danger, as is also the

[1] As already stated (p. 199), lead foil is more satisfactory than the tin foil usually recommended, since not only does it give a better impression, but also one that is easier to photograph. If this rolling is to be exhibited in Court it should be pinned to a piece of cardboard by the four corners and either put into a frame covered with glass (not touching) or into a shallow box with a glass cover.

[2] This method is much better than that with paper covered with carbon duplicating paper recommended by Georgiades (*Annales de Méd. lég.*, 1922, p. 30). If the rolling is coated with a colourless varnish it serves all the purposes of a photograph.

[3] A. R. Moritz, *The Police Journal*, **11** (1938), pp. 364–369.

possibility of incomplete contact between the coated celluloid or cellophane and the bullet at every point during the making of the impression.

The impression obtained is useful for measuring the width of the lands and grooves and for determining the pitch ; for showing to others (for example in Court) and for photographic purposes, but no matter how carefully it may be made, or which of the several materials mentioned may be used, the result is chiefly of value for the major marks and may be of little or no use as a representation of the secondary marks, which if they reproduce at all may be incomplete and unsatisfactory. Béroud [1] in certain cases of coated bullets cuts off the upper unmarked portion of a bullet, melts out the lead from the bottom marked portion, cuts through this vertically in a place where either there are not any marks or where the marks are not of importance, flattens out the ring of metal so obtained with a rubber roller and thus has the marked portion of the bullet as a flat strip. This tends to distort the finer marks and therefore is open to adverse criticism on that ground ; it also defaces the bullet under investigation, which is undesirable, and would not be allowed by the Court.

The only satisfactory method of examining and comparing the secondary marks on bullets is by means of a comparison microscope [2] and special bullet holders that permit both bullets to be turned together or one turned separately, the bullets being mounted by means of clay, plasticine or wax in a horizontal plane, both pointing in the same direction. The bullet holders are movable in two directions in the horizontal plane and in the majority of instruments there are special arrangements for lowering or raising the bullet holders (with the bullets), thus providing a quite simple and convenient method of focussing each bullet separately. With this instrument the magnified images of the corresponding portions of two bullets may be brought together in one field, each image occupying one-half of the field, thus making comparison easy. A low magnification should be used, one of from about ten to twenty diameters being satisfactory. Considerable care is necessary when examining fine incised lines on a brightly illuminated metallic surface, or when examining photomicrographs of such objects, as there is a great liability to errors of interpretation owing to the effects of reflection and of shadows, unless the observer has had considerable experience in such work. Photomicrographs of markings on different bullets that are found to match should be made for exhibition in Court.

No matter how carefully projectiles and fired cartridge cases are examined,

[1] H. Ashton-Wolfe, " The Scientific Side of the Detection of Crime," *Illustrated London News*, 7th July, 1928, p. 18 ; also H. Söderman, *L'Expertise des Armes à Feu Courtes*, 1928, p. 79.

[2] Although this well-known principle had been employed previously for other purposes, apparently it was first applied to the examination of bullets by Mr P. O. Gravelle.

the facts obtained are useless, unless and until a weapon is found that corresponds with them, which may not be for months or years afterwards, or which may never happen. Thus from 1919 to 1924 inclusive a large number of political crimes were committed in Egypt, including more than twenty murders and attempted murders by shooting, culminating in the murder of the Sirdar of the Egyptian Army. In eighteen of these cases the bullets and the fired cartridge cases were examined by me, as a result of which I was able to state the nature of many of the weapons used and also that several of them had been employed for more than one of the crimes, but this did not help to catch the criminals, as until the last murder (that of the Sirdar), although a large number of seized weapons were examined, none corresponded with the bullets and cartridge cases. After the murder of the Sirdar, however, four self-loading pistols were found and examined by Sydney Smith [1] which had been used, not only for the murder of the Sirdar, but some of them also in the previous shootings.

Slugs. These should be examined for (*a*) adherent foreign material [2]; (*b*) composition; (*c*) dimensions, and (*d*) weight.

Composition. Slugs are composed of soft lead, which, being of commercial quality, generally contains small proportions of antimony and tin and occasionally traces of arsenic. Eleven slugs from different cartridges that were analysed all contained antimony, the amount ranging from 0·30 per cent. to 0·90 per cent. Five of these slugs did not contain tin, while six contained tin, which varied in amount from 0·17 per cent. to 0·55 per cent. Arsenic was present in several instances, but only as a trace.

Dimensions. The slugs from any one cartridge usually are of a similar, though not absolutely identical, size, but there are exceptions to this, and occasionally different sized slugs occur in the same cartridge; thus in one cartridge examined there were six slugs, four of approximately the same size and shape and two only half the thickness of the others. Amateur-made slugs are of very irregular shape and size.

A square slug may become so distorted on impact against a hard body as to make an almost round hole, and when found may be round or oval with definite "mushrooming," and may show little or no evidence of having been square. The presence of straight lines or slight ridges, which sometimes are all that remains of the edges of the slug, should be searched for specially.

Weight. Although the slugs from any one cartridge are generally nominally of the same weight, this is not always the case, and in the cartridge referred to above, in which there were six slugs, four of one size and two

[1] Sydney Smith, "The Identification of Firearms and Projectiles," *The Police Journal*, **1** (1928), pp. 411–22.

[2] See the examination of bullets, p. 215.

of another size, the mean weight of the former was 1·80 grams and the mean weight of the latter 1·07 grams. In other cartridges examined the weight of the individual slugs has varied as follows: in cartridge (*a*) from 1·71 to 1·78 grams; in cartridge (*b*) from 1·78 to 1·83 grams, and in cartridge (*c*) from 1·65 to 1·82 grams. The number of slugs in a large number of cartridges examined has been 6, 7 and 11 respectively.

Small Shot. Originally English small shot was of two kinds, "soft" and "hard" or "chilled." Both these kinds of shot were made of ordinary commercial lead, to which a small proportion of arsenic (0·3 to 0·8 per cent.) was added for hardening purposes, and to enable the lead better to assume the spherical shape when the molten metal was dropped into water. Hard or chilled shot was cooled by means of a blast of cold air, which was supposed to cause the metal to harden more than was the case with shot not so treated. Shot is now hardened, however, by the addition of antimony, sometimes about 12 per cent., but when so made, frequently it is still termed "chilled."

On one occasion some small shot examined was found to consist of iron; it was coated with graphite, was irregular in shape and varied in size in the same cartridge.

The question of the size of the shot is sometimes of considerable importance, as for example in the Monson trial.[1] In this case there were two guns involved, one a 12-bore gun with which No. 5 shot was used and the other a 20-bore gun with which No. 6 shot was used, and a great deal depended upon from which of the two guns the fatal shot had been fired. Four pellets were found in the brain of the victim, and both the prosecution and the defence agreed that the weight of these pellets established the fact that death had been caused by a discharge from the 12-bore gun loaded with No. 5 shot. In view of the importance of the size and weight of shot, the following few determinations made by me may be recorded:

		A.	B.	C.	D.
Size of Shot		10	10	6½	7
Bore of Gun		12	12	12	12
Number of Cartridges examined		5	6	12	12
Weight of Shot in Cartridge (grams)	Min.	31·7	31·5	24·5	32·1
	Max.	32·8	32·2	31·0	33·0
Number of Pellets in Cartridge	Min.	1,377	983	184	383
	Max.	1,988	1,097	290	397
Diameter of Pellets (mms.)	Min.	0·90	1·72	2·26	1·93
	Max.	3·50	1·75	3·07	2·63

From the above facts it is evident that not only does the number of pellets sometimes differ considerably in cartridges of the same make, but that the size of the pellets may vary in the same cartridge, and therefore great care

[1] J. W. More, *Trial of A. J. Monson*, 1908, pp. 58, 79, 276, 359, 365, 426, 463.

is required in making any general deductions from the size and weight of isolated pellets.

The size and weight of shot in a charge depend upon the size of the cartridge, which varies with the bore of the gun. The approximate number of shot may be calculated from the published tables [1] of shot sizes, which give the bore of the gun, the weight of the shot and the number of pellets per ounce.

Shot Marks. These have been dealt with in connexion with the subject of Clothing.[2]

Range of Shot. The distance from which a shot has been fired is calculated from the presence or absence of scorching (singeing), blackening and powder residue found round the bullet hole when the shot is from a rifle, revolver or self-loading pistol and, in the case of a shotgun, also from the number and distribution of the holes and marks made by the pellets or slugs.

Although, as a rule, problems concerning the range of shot should be left to sportsmen and gunsmiths, it is well that the chemical expert should have some knowledge of the matter, since he may be (and should be) consulted when any chemical testing is required in connexion with the possible presence on the clothes or skin of the victim of the products of the combustion of the powder, or of traces of metal from a projectile, such as lead from an uncoated lead bullet or from pellets or slugs.

Frequently no clear distinction is made between scorching, blackening and tattooing, although they are very different.

Scorching is the discoloration resulting from burning by the flame or hot gases that issue from a firearm. Certain of the gases produced by the combustion of gunpowder (hydrogen, carbon monoxide and methane from black powder and hydrogen and carbon monoxide from nitro powder) generally take fire on coming in contact with the oxygen of the air and produce a momentary flame, which in the case of a rifle, self-loading pistol or shotgun is seen at the muzzle of the weapon, but which with revolvers is seen between the cylinder and the barrel, as well as sometimes also at the muzzle.[3] Burrard states that "With a service rifle scorching may occur up to 6 inches; and with a revolver or pistol up to 2 to 3 inches." [4]

[1] These may be found in the manufacturers' catalogues, but the figures given are only nominal and approximate. The English designation of shot is not used either on the continent of Europe or in the United States of America, different marks and numbers being there employed, which may be found in the catalogues. In France there are three different systems in use, namely those of Paris, Marseilles and Lyons.

[2] See pp. 54–55.

[3] In one instance in my experience the use of nitro powder some 30 years old (which had been kept in Egypt and must have been in an highly unstable condition) produced a long flame at the muzzle of a revolver.

[4] G. Burrard, *op. cit.*, p. 62.

Blackening generally consists, wholly or largely, of smoke (made up of very minute particles of carbon of the order of from one one-thousandth of a millimetre to one one-hundred-thousandth of a millimetre in diameter [1]) produced by the combustion of the powder, but with the smoke there may be also a small proportion of larger black particles, consisting of carbon or carbonaceous matter. Even non-graphité-coated " smokeless " powder produces a small amount of smoke, which may mark objects at close range, while graphite-coated " smokeless " powder produces slightly more smoke and black powder (because it contains charcoal) produces still more smoke with a resultant increased range of blackening. Burrard states [2] that " Blackening with a high-power rifle, such as a service rifle, can occur up to about 9 inches, and with a revolver [3] or pistol [3] up to about 6 inches," the range, however, naturally being increased when black powder is used, which Burrard estimates in the case of a revolver or self-loading pistol to be " about 8 inches," [4] while with a shotgun it is " about 12 inches." [4]

Tattooing, as its name indicates, is the marking or " peppering " of an object caused, in the case of weapons firing bullets, by unburnt or partly burnt powder grains, which is much more common with revolvers and self-loading pistols than with rifles, owing to the less complete combustion of the powder in short-barrelled weapons. With shotguns firing pellets there will be also the marks of the pellets, or even the pellets themselves. In the case of tattooing (other than that caused by pellets), as seen on cardboard targets with shots fired with nitro powder from revolvers or self-loading pistols, the bullet hole at short range (usually up to about 6 inches) is ringed with powder grains, which when they become detached (as readily occurs on handling the target) leave correspondingly-shaped indentations in the cardboard. Even at a distance of a foot there may be tattooing, though naturally less than at shorter range, and occasionally with old ammunition at still greater distances.

Analysis of Projectiles. Whatever the nature of the projectile is, occasionally it may be necessary to analyse it, especially if of lead, for example in the case of amateur-made bullets or slugs in order to compare the composition with that of any lead found in the possession of a suspected person.

As a rule in shooting cases the amount of material available is very small, since not only is the total amount small, but of this as large a quantity as possible must be reserved for further analysis or for production in Court. In such cases when a comparison between several different samples of lead only is required the following method will be found useful: Take half a

[1] W. E. Gibbs, *Clouds and Smoke*, p. 130.
[2] G. Burrard, *op. cit.*, p. 63.
[3] Firing nitro powder.
[4] G. Burrard, *op. cit.*, p. 64.

gram of each sample in a finely divided condition, put into separate small conical flasks and add to each 5 grams of ammonium sulphate [1] and 10 c.c. of strong sulphuric acid and heat until the metal is all dissolved and the precipitated lead sulphate is white or practically white. Although the bulk of liquid is small, there is no fear of the flask breaking. The lead is fully precipitated as sulphate and any arsenic, antimony and tin present remain in solution.[2] Cool and add to each flask 25 c.c. of a 10 per cent. solution of tartaric acid. This prevents the antimony and tin from being precipitated by the water, which, if it were not added with the tartaric acid, would have to be added to dilute the solution before filtration. Shake well and boil for five minutes in order to granulate the sulphate of lead. Filter into Nessler tubes, using ordinary filter paper and making no attempt to transfer all the lead sulphate to the paper, and wash with dilute sulphuric acid (10 per cent. solution) using a minimum quantity and approximately the same amount in each case. To the filtrates add a saturated solution of sulphuretted hydrogen. Make up to the same volume (50 c.c.) with water in each case, stir well with a glass rod and compare. The contents of the tubes may be transferred to glass-stoppered bottles and preserved for presentation in Court.[3] If tall narrow bottles of clear glass are used, the different amounts, colours and general appearance of the various precipitates are very marked and demonstrate the results in a manner that no mere recital of percentages can possibly do.[4] If required, this method may be made quantitative, in which case, however, the filtration from the lead sulphate should be through asbestos, using a Gooch crucible. The antimony and tin are determined best volumetrically, after separating any arsenic present, the former by means of potassium permanganate and the latter with iodine.

The precipitate formed on the addition of sulphuretted hydrogen will be composed of one or more of the following named compounds : (*a*) arsenic sulphide (As_2S_3) which is lemon yellow : (*b*) antimony sulphide (Sb_2S_3) which is orange : (*c*) tin sulphide (SnS_2) which is yellow. Copper sulphide (black) which is sometimes present in small amount, may darken the precipitate.

If quantitative results are required the analysis is continued as follows : Filter, using a small paper, and wash with sulphuretted hydrogen water. Transfer the paper with the precipitate to a small beaker and warm with

[1] If more than about 5 per cent. of tin is present, the ammonium sulphate should be omitted.

[2] Owing to the fact that stannic sulphate tends to form and that this compound is insoluble in strong sulphuric acid, there is danger of some tin being left with the lead, and the lead sulphate therefore should be tested for tin.

[3] If the bottles are filled completely and are provided with well-fitting stoppers coated with wax, the contents remain practically unchanged for a considerable time.

[4] Several specimens of the comparison projectiles should be analysed, as these may show appreciable differences in composition among themselves.

10 c.c. strong hydrochloric acid until the sulphides of antimony and tin are dissolved and the sulphuretted hydrogen is all expelled, which may be tested for by removing a small portion of the solution with a pipette, and diluting it largely with water. If a coloured precipitate is produced, the operation is not yet complete and the portion tested must be returned to the main bulk of solution and the heating continued. The liquid must not boil, or chloride of antimony may be lost. When all the sulphuretted hydrogen is expelled, dilute the liquid with water. If antimony is present, a slight milkiness due to basic chloride is produced. Add dilute hydrochloric acid drop by drop until the liquid clears. Filter through asbestos, using a Gooch crucible, and wash well with water acidified with hydrochloric acid.

Residue. This will consist of arsenic sulphide.[1] If more than a trace, the amount may be determined quantitatively as follows: Wash the residue on the filter with water, dry and weigh. Treat repeatedly with hot ammonium carbonate solution, which dissolves the arsenic sulphide, wash, dry and again weigh. The difference between the two weights represents arsenic trisulphide.

Arsenic also may be separated from antimony and tin by distillation, the method depending upon the volatility of arsenic trichloride, the arsenic being determined volumetrically by titration with iodine.

Solution. Dilute to 200 to 250 c.c. Titrate with $\frac{N}{20}$ potassium permanganate solution.

$$5SbCl_3 + 16HCl + 2KMnO_4 = 5SbCl_5 + 2KCl + 2MnCl_2 + 8H_2O$$

The potassium permanganate should be standardized with tartar emetic, which contains 36·16 per cent. of antimony. Copper in small amount does not interfere.[2] After titration of the antimony boil the solution down to about 150 c.c. Add 50 c.c. strong hydrochloric acid and about 0·05 gram metallic antimony dissolved in 5 c.c. strong sulphuric acid. Add a small rod of pure soft iron. Both the antimony and iron are for the purpose of reducing the tin to the stannous condition, and either may be used alone. Nickel or lead sometimes is employed instead.[3] Boil gently for about an hour. Transfer the solution quantitatively, without the iron, by means of boiling water to a small conical flask containing about two inches of pure thin iron wire and a small quantity of hydrochloric acid which have been generating hydrogen for about two minutes. Boil gently until all the wire is dissolved (about five minutes). Cool in ice in an atmosphere of carbon

[1] And disintegrated filter paper.

[2] W. H. Low, "Determination of Antimony and Tin in Babbitt, Type Metal or other Alloys," *Journal American Chemical Society*, **29** (1907), pp. 67–74.

[3] A new and satisfactory method using hypophosphorous acid as reducing agent has been published (B. S. Evans, *Analyst*, **56** (1931), pp. 171–7).

dioxide. This is essential to avoid oxidation of the stannous chloride. When cold, titrate with $\frac{N}{10}$ iodine solution, using starch solution as indicator.

$$SnCl_2 + I_2 + 2HCl = SnCl_4 + 2HI$$

Iron, lead and antimony do not interfere.[1] Copper in quantities below three per cent. does not interfere.[1] [2]

Illustrative Cases. 1. Some white metal adhering to a piece of lead with which a man had been shot, but fortunately not wounded, was found not to be nickel, as was at first supposed, and which would have indicated a nickel-coated bullet, but silver from a cigarette case that had been penetrated. A night watchman suspected of the crime escaped conviction because the projectile did not agree in composition with the slugs in the cartridges with which he was supplied.

2. A man who was suspected of wounding another by shooting escaped conviction because the shot from a cartridge seized in his house was found on chemical analysis to differ in composition from the shot extracted from the wounded man, the former containing a comparatively large amount of tin and the latter containing no tin but a trace of antimony.

3. In a somewhat similar case to the one just mentioned a night watchman shot at some unknown persons suspected to be thieves, who, however, all escaped. In the morning, blood was found on the ground and subsequently a man was arrested with a shot wound in his leg for which he failed to give any satisfactory explanation. Analysis proved that the lead extracted from the wound did not agree in composition with the slugs in the watchman's cartridges and the man was released. The impurities present in the lead were the same in each case and consisted chiefly of antimony, but the shot from the wound contained much less antimony than the slugs. It should not be forgotten that projectiles from the same manufacturer are not always made from the same supply of lead and also that differences in composition may be due to the lead, even from the same supply, not being homogeneous in composition. In this case, however, other shots besides those of the watchman were fired and it is possible that the watchman did not hit anyone and that the wounded man had been shot accidentally by one of his companions.

4. In one case two slugs found in the house of a person accused of murder by shooting agreed in composition with the lead extracted from the brain of the victim. In another case a distorted slug from the victim contained a greater proportion of impurities, notably of antimony, than the slugs found in possession of a suspected person.

[1] W. W. Scott, *Standard Methods of Chemical Analysis*, **1** (1926), pp. 533, 536 (*b*).
[2] W. H. Low, "Determination of Antimony and Tin in Babbitt, Type Metal or other Alloys," *Journal American Chemical Society*, **29** (1907) pp. 67–74.

5. A distorted slug and six small pieces of very thin metal were extracted from the body of a man who had been shot. The slug contained antimony but not tin and the small pieces of metal consisted of pure lead. Certain suspected cartridges were examined also. These contained seven slugs enclosed in thin sheet lead, which latter was free from both antimony and tin. The slugs were exactly of the same composition and thickness as that from the murdered man. There can be little doubt, therefore, that the cartridge with which the man had been shot was identical with those examined and that the thin pieces of lead were the wrapping of the slug and not parts of another slug.

6. In the Gutteridge murder case [1] certain marks on the breech face of a revolver in the possession of one of the accused were reproduced on the cap of a fired cartridge case found in connexion with the crime.

7. In the case of the murder of the Sirdar of the Egyptian army it was proved by Sydney Smith [2] that on the cartridge cases from the scene of the murder and on the bullets from the body of the victim there were marks identical with those made by certain weapons seized.

8. In a recent murder case in Palestine, fourteen different marks at the bottom of the indentation made by the striker on a cartridge case found on the scene of the crime were proved by Baker [3] to be identical with those made by the striker of the rifle of the accused person. Marks made by the extractor on the cylindrical portion of the cartridge case also were characteristic. In this case I acted as expert for the defence, but the evidence of the identity of the markings both on the cap and on the cartridge case with those made by the accused's weapon was so conclusive that I could only confirm the report of the expert for the prosecution.

9. In the Sacco-Vanzetti case, one of the bullets from the murdered man and one of the fired cartridge cases from the scene of the murder were proved by Goddard [4] to have been fired from the Colt self-loading pistol found in possession of one of the accused persons.

10. In the case of the murder of Dr. Arlosoroff at Tel Aviv, Palestine, in 1933 (in which I acted as expert for the defence), the fatal bullet was most unusual, since it had only three lands and three rifling grooves (with a right-hand twist). It was a Nagant bullet [5] which had been fired almost certainly with smokeless powder. At various periods during the trial four different weapons of the requisite calibre (three of which were connected

[1] W. T. Shore, *The Trial of F. G. Browne and W. H. Kennedy*, 1930, pp. 105–9; Figs. 1, 2, 3 (pp. 23, 24, 25).

[2] Sydney Smith, "The Identification of Firearms and Projectiles," *The Police Journal*, 1 (1928), pp. 411–22.

[3] G. W. Baker, "Scientific Evidence Relating to Firearms, with Special Reference to a Recent Murder Trial," *Analyst*, 55 (1930), pp. 738–44.

[4] C. H. Goddard, "Who Did the Shooting?" *Popular Science Monthly*, Nov., 1927, pp. 21–2, 171–2.

[5] See p. 214.

with certain possible actors in the tragedy) were suspected, either by one side or the other. Two of these were self-loading pistols, which would not take the Nagant ammunition and one of them had a left-hand twist: one was a revolver of the Nagant type (though not a true Nagant), which like a true Nagant had four rifling grooves with a right-hand twist, and the other was an ordinary revolver with five lands and five grooves and a left-hand twist and the barrel was in much too worn and corroded a condition for the fatal bullet to have been fired from it.

II. WAR CASES 1940–1944.

Weapon.	Questioned.		Comparison.		Result.				Nature of Weapon.
					Bullets.		Cartridge Cases.		
	Bullets.	Cartridge Cases.	Bullets.	Cartridge Cases.	Positive.	Negative.	Positive.	Negative.	
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	
Rifles									
26 (12 cases)	12	5	81	94	5	7	5	...	British, ·303 inch.
1 . .	0	1	4	4	...	...	1	...	German, 7·9 mm. (·311 inch).
1 . .	1	3	...	...	1	...	3	...	American Springfield, ·3 inch.
Revolvers									
3 (2 cases)	2	1	9	9	1	1	1	...	British (Enfield), ·380 inch.
1 . .	1	3	3	3	...	1	3	...	Italian (Castelli), 10 mm. (·39 inch).
1 . .	1	1	3	3	1	...	1	...	Smith & Wesson, ·45 inch.
7 (8 cases)	6	12	17	17	6	...	12	...	Smith & Wesson, ·38 inch.
1 . .	0	1	...	...	...	...	1	...	Smith & Wesson (imitation), ·32 inch.
2 (2 cases)	2	2	5	5	1	1	2	...	Webley, ·455 inch.
Self-loading Pistols									
1 . .	1	0	6	6	...	1	...	...	Colt, ·38 inch.
3 (3 cases)	3	6	12	12	1	2	5	1	Italian (Beretta), 9 mm. (·354 inch).
1 . .	0	1	...	...	...	...	...	1	Luger-Parabellum, 9 mm. (·354 inch).
0 (1 case)	1	0	...	...	...	1	...	...	Not identified, 9 mm. (·354 inch).
Sub-machine Gun									
1 . .	1	0	4	0	...	1	...	...	Thompson, ·45 inch.
Machine Gun									
1 . .	2	0	32	0	...	2	...	...	British, ·303 inch.
Total (37 cases)	33[1]	36[2]	176	153	16[1]	17[1]	34[2]	2[2]	
Percentage .	...	...	...	...	48·5	51·5	94·5	5·5	

[1] In one case not included there was neither weapon, nor bullet, nor cartridge case, but only a hole in a hat. See also tabular statement following. (Bullet Evidence).
[2] See also tabular statement following. (Cartridge Case Evidence).

BULLET EVIDENCE

Serial No.	Weapon.	Positive.	Negative.	Remarks.
3/41	6 Rifles, ·303 inch . .	...	—	
6/41	2 Revolvers, ·380 inch .	...	—	
6/41	Self-loading pistol, ·38 inch	...	—	
9/41	Revolver, 10 mm. . .	—	...	
20/41	Rifle, ·303 inch . . .	...	—	
2/42	2 Self-loading pistols, 9 mm.	...	—	
8/42	2 Rifles, ·303 inch . .	...		Fragments only.
30/42	Rifle, ·303 inch . . .	...	—	One tiny fragment.
43/42	Sub-machine gun . .	...	—	
45/42	Revolver, ·45 inch . .	—	...	
62/42	13 Rifles, ·303 inch . .	...		
73/42	Revolver, ·38 inch . .	—	...	
11/43	Rifle, ·303 inch . .	...	—	Fragment of envelope only.
17/43	Rifle, ·303 inch . .	...		Part only.
23/43	Rifle, ·303 inch . .	...		Wrong bullet.
29/43	Revolver, ·38 inch . .	...		
31/43	Self-loading pistol, 9 mm. .	—	...	
48/43	Revolver, ·38 inch . .	—	...	
50/43	Rifle, ·3 inch . . .	...		Small fragments.
70/43	Self-loading pistol, 9 mm. .	...	—	Pistol not found.
17/44	Rifle, ·303 inch . . .	...	—	
21/44	Revolver, ·455 inch . .	...	—	
31/44	Rifle, ·303 inch . . .		...	Nature of weapon only required.
44/44	Self-loading pistol, 9 mm. .	...	—	
53/44	Revolver, ·455 inch . .	—	...	
85/44	Self-loading pistol, 9 mm. .	...		Whether fired recently.
93/44	Revolver, ·38 inch . .	—	...	Nature of weapon only required.
100/44	Revolver, ·38 inch . .	—	...	
101/44	Revolver, ·38 inch . .	—	...	
104/44	Revolver, ·38 inch . .	—	...	
	Total . .	11	19	
	Percentage .	36·5	63·3	

Six interesting cases are as follows :- -

(*a*) This was a murder case in which the weapon used was a British army rifle. The fatal bullet was in three pieces, the largest of which was much flattened, but the lands and grooves and secondary marks on it were definite and distinct. The cartridge case was not found. Five persons were arrested on suspicion and a comparison bullet was fired from each of four of their rifles. The fifth rifle, which belonged to the chief suspect, will be dealt with later. Three of the bullets had secondary marks, which, however, did not correspond with those on the fatal bullet. The fourth bullet was practically free from secondary marks, either on the lands or in the grooves, and from this rifle three more bullets were fired, two of which also were practically without secondary marks, while the third was well and

CARTRIDGE CASE EVIDENCE

Serial No.	Weapon.	Firing Pin Marks.		Breech Marks.		Extractor Marks.		Ejector Marks.	
		C.[1]	N.C.[2]	C.[1]	N.C.[2]	C.[1]	N.C.[2]	C.[1]	N.C.[2]
9/41	Revolver, 10 mm.	+	...	+	...	...	...	...	...
2/42	2 Self-loading pistols, 9 mm.	...	+	...	+	...	+	...	+
45/42	Revolver, ·45 inch	+	...	...	+	...	...	...	...
73/42	Revolver, ·38 inch	+	...	+	...	...	...	...	...
18/43	Rifle, 7·9 mm.	+	...	+	...	...	+	+	...
29/43	Revolver, ·38 inch	+	...	+	...	...	...	...	...
31/43	Self-loading pistol, 9 mm.	+	...	...	+	...	...	+	...
48/43	Revolver, ·38 inch	+	...	...	+	...	...	...	...
93/43	Revolver, ·38 inch	+	...	+	...	...	...	...	...
7/44	Rifle, ·303 inch	+	...	...	+	...	...	...	...
21/44	Revolver, ·455 inch	+	...	...	+	...	...	...	...
27/44	Rifle, ·303 inch	+	...	+	...	...	+	...	+
53/44	Revolver, ·455 inch	+	...	+	...	...	...	...	...
82/44	Revolver, ·32 inch	+	...	+	...	...	...	...	...
100/44	Revolver, ·38 inch	+	...	+	...	...	...	...	...
101/44	Revolver, ·38 inch	+	...	...	+	...	...	...	...
104/44	Revolver, ·38 inch	+	...	+	...	...	...	...	...
	Total	16	1	10	7	...	3	2	2
	Percentage	94·0	6·0	59·0	41·0	...	...	...	...

C.—Characteristic. N.C.—Non-characteristic.

deeply engraved, but the marks did not correspond with those on the fatal bullet. Eight more rifles were then taken from other possible suspects and three bullets were fired from each. Of these twenty-four bullets twenty-three were practically free from secondary marks, either on the lands or in the grooves, only one being well and deeply engraved, but the marks on it did not agree with those on the fatal bullet. From the rifle of the chief suspect three bullets were fired, all of which were practically without secondary marks. Thus, out of thirty-four bullets from thirteen rifles, only five had secondary marks, two being well and deeply engraved, but the engraving on the other three, though definite, was neither considerable nor deep. All the rifles were about twenty-five or twenty-six years old and had been in regular use during that time, and I suggest as the explanation of the practical absence of secondary marks on most of the bullets, that, although the barrels were all considerably and deeply engraved, the bores had become so enlarged by constant use and cleaning that the majority of the bullets were not large enough to take the secondary marks, and it seems probable that the few bullets that were well marked, including the fatal bullet, although nominally the same size as the rest, actually were of a slightly greater diameter.

(*b*) This case also was a murder and also with a British army rifle, and

was very similar to the previous case. The fatal bullet was in five pieces, one of which, however, had engraved on it the greater part of five lands and five grooves on all of which there were a large number of secondary marks. The first experimental bullet out of seven fired passed through the cotton placed to receive it and was so much scratched by the sand behind that it was useless. Three other bullets were found in the cotton so broken up as also to be useless, the reason for which was not investigated. The remaining three bullets had very few, and these non-characteristic, secondary marks, which did not agree with those on the fatal bullet, on which the marks were well engraved. The cartridge case from the fatal bullet was not found. The practical absence of secondary marks on the experimental bullets was probably due, as in the previous case, to the fact that the rifle was a very old one that had been much used and much cleaned, with the result that the bore was so much enlarged that only an exceptionally large bullet took the secondary marks.

(*c*) This was as follows: As a train left a certain station in Egypt, a British soldier, wearing spectacles, was leaning out of the window, and a man on the platform rushed forward and stole the spectacles. The soldier picked up his rifle, which was loaded, contrary to regulations, and shot at the thief, but, being unable to see well without spectacles, missed him, and fortunately also missed everyone else on the platform. The bullet, however, hit some hard object, probably part of the station building, which caused it to ricochet, and it struck in the head and killed another British soldier who was standing up and looking out of the window of a compartment of the same train several carriages behind, and then passed out of the open window on the far side of the carriage and was never found. I analysed several small particles of metal taken from the head of the dead man and found them to be lead, the cupro-nickel coating of the bullet manifestly having been stripped off and only a small part of the lead core having hit the victim.

(*d*) This was an instance of the confusion of exhibits and is included because, though most unusual, it manifestly may happen. Two shots were fired from ·303 rifles at two thieves, who were escaping with stolen rifles. One of the thieves was hit and subsequently died in hospital. The bullet received from the hospital as having been extracted from the wounded man, and which I examined, was a ·455 revolver bullet, having on it blood and fragments of tissue. On enquiry, it was found that no such bullet had been extracted from the particular victim, the one with which he had been shot having passed through the body. The origin of the bullet submitted and the cause of the mistake were not investigated by me.

(*e*) In another case in which a man had been severely wounded by a bullet fired from a self-loading pistol, it was proved that neither of two

pistols of similar calibre and rifling found on the premises where the shooting (which was unpremeditated and done by a drunken man) took place had been used. These pistols almost certainly had been in the illegal possession of persons on the premises and had been discarded because a search was being made of those present.

(*f*) This was a case of wounding by a Smith and Wesson ·45 revolver, and it was proved from the agreement between the secondary marks on the bullet fired and those on the comparison bullets that the suspected revolver had been used. One peculiarity was that, probably largely owing to the oily and dirty condition of the breech face, the heads of the cartridge cases did not make contact with this and, therefore, were not marked, although the marks on the breech face were characteristic. The shooting was admitted, but it was stated that the revolver had dropped on the floor and accidently had been discharged. There was not any evidence to support this, and the fact that two live cartridges in the cylinder bore indentations made by the firing pin of the revolver showed that the shooting had been deliberate, since it had been preceded by two previous attempts, which had missed fire, these misfires being due to the very small distance the point of the firing pin projected through the breech face on discharge.

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CHAPTER XII

MICROSCOPY; PHOTOGRAPHY; X-RAYS; ULTRA-VIOLET RAYS AND INFRA-RED RAYS

Microscopy

The chemico-legal expert would be very helpless without a microscope, since there are few examinations in which this instrument, either in its simple form of a lens or in its more complex form of a compound microscope, is not used. One great advantage the microscope has over chemical analysis is that it does not destroy the material tested. The microscope is essential for the proper examination of documents; fibres; the markings on cartridge cases and projectiles; dust and dirt; in blood testing for the examination both of hæmin crystals, and in conjunction with a spectroscope, for the examination of the various derivatives of hæmoglobin and for the recognition of the crystals formed in the testing of alkaloids with such reagents as picric acid and gold chloride. For general purposes any good microscope may be used, and no particular make is recommended, each kind having its own merits. As a rule magnifications of from 10 to 400 diameters will be required.

For use with documents a particular form of microscope or stage is necessary in order to avoid folding the documents. Osborn [1] illustrates a special document microscope, but I have found the " Process " microscope [2] a very useful instrument for ordinary purposes, though it cannot be used for delicate work such as taking precise measurements since the arm is not rigid and it has the advantage of not being expensive. This is made for the examination of lithographic stones and zinc and aluminium plates, and has no stage at all, the tube carrying the objective and eyepiece being at the end of a long arm that reaches over the document, which therefore can be examined without folding. With a No. 2 eyepiece and a 1-inch objective, this instrument gives a magnification of 48 diameters, and with a $\frac{2}{3}$-inch objective a magnification of 72 diameters, and as a rule nothing more than this is required. For the measurement of the width of ink lines in a written document or of the size of the letters in a typed document, as also for the measurement of fibres, the microscope should be provided with a good micrometer, either a simple micrometer to be inserted into the eyepiece or, better, a screw-micrometer eyepiece.

For the examination of erasures and crossed lines in documents, for coins and for the markings on cartridge cases and caps a binocular stereoscopic

[1] A. S. Osborn, *Questioned Documents*, 1929, p. 65.
[2] Made by Messrs. R. & J. Beck, Ltd., London.

erecting microscope is recommended, without stage, but having a special stand and provided with three pairs of eyepieces and three pairs of objectives giving magnifications ranging from 9 to 103 diameters. This instrument [1] has the advantage of giving an erect image instead of the inverted image of the ordinary microscope.

A comparison microscope or a comparison eyepiece that may be used with two ordinary microscopes with which, by means of an arrangement of prisms, the magnified images of two objects may be brought together in one field, each image occupying one half of the field, is essential for the comparison of the markings on two bullets [2] or of the exact tint of two coloured objects.[3] A simplified micro-comparator for large objects is described by Stirling.[4]

For the examination of crystals, mineral fragments, insoluble residues from analytical processes and dust and dirt of mineral origin, a polarizing apparatus will be found useful, and for general use a mechanical stage is a great convenience though not essential.

Four different kinds of lens are recommended, a good high-power folding lens for the pocket, a good reading glass with a handle for examining objects to which a pocket lens cannot be applied, a watchmaker's eye-glass in an aluminium frame and a " counting glass " with a field a square inch in size such as is used in the cotton trade. This last is a very useful type of lens on account of the large size of the field and because, being in a stand, it can be placed on the article examined, thus leaving both hands free.

Photomicrographs often are very useful, and it has been suggested that for legal cases a permanent record taken by means of photomicrography should be made of everything examined under the microscope. While there is no doubt that photomicrographs should be utilized more often than usually is done in order to demonstrate in Court facts that can be seen only under the microscope, in actual practice it will be found impossible to take a photograph every time the microscope is used.

As already mentioned,[5] I am not in favour of taking a microscope into Court, since only those who have been trained specially can either use a microscope or appreciate what they see : a microscopal demonstration, too, occupies considerable time and requires a much better light than is available in most Courts, and all the advantages arising from it may be attained better and more easily by the use of photomicrographs.

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[1] Made by Zeiss. [2] See p. 231. [3] See p. 83.
[4] W. Stirling, *Analyst*, 58 (1933), pp. 684–6. [5] See p. 20.

Photography

Although the value of photography in criminal investigation is well known, and although photography is being gradually employed more and more, it is not yet made use of to anything like the extent that is possible. In chemico-legal work photography is most important, and every expert should himself be a good photographer, not necessarily in order to take all the photographs required, but more particularly that he may realize the use and also the limitations of photography and so be in a position to know exactly what is required and how the best results may be obtained, and also that he may be able to do the work if at any time a professional photographer is not available. It is, however, generally uneconomical for the expert to undertake personally the photography needed for his work, and he should have access to a fully equipped photographic laboratory with all the technical assistance and apparatus necessary for taking any photographs required, including enlargements and photomicrographs.

There are few branches of chemico-legal work in which photography is not at some time helpful, but it is more particularly needed in connexion with bullets and empty cartridge cases, counterfeit coins, questioned documents, finger prints, robbery from letters and parcels and stains and marks. A few special cases of the use of photography may be considered.

Counterfeit Coins. Photography is not as a rule necessary for any examination of counterfeit coins, but photographic enlargements are very helpful for attaching to the report or for exhibition in Court, as they allow similarities in various counterfeit coins or differences from genuine coins to be demonstrated readily. Considerable difficulty will be experienced in photographing coins successfully. This is due to the low relief of the design and the consequent absence of contrast in light and shade. There also may be difficulty arising from reflection from the surface of the coin, especially if this is new. The first difficulty may be overcome by arranging the coins in such a manner that they receive the light from one side and at an angle to the surface, so that the shadows formed increase the relief. In order to keep the coins in position while being photographed they should be fastened to a piece of cardboard by means of beeswax or plasticine. Slow plates should be used, " process " plates or lantern slides being particularly good. For printing, " bromide " or " gaslight " paper is recommended.

A simple and effective method of photographing coins is described by Guebhard.[1] This consists in fogging very slightly, by the briefest possible exposure, an ordinary photographic plate, placing this in a dish already containing sufficient developer to cover it, then putting the coins directly on to the sensitized surface of the plate and allowing development to proceed. After the lapse of a few minutes the plate is taken out and fixed in the usual

[1] *La Nature*, 1898, p. 128.

way. All the operations, except of course the preliminary fogging, are done in a dark room. Another still better method, also without a camera, is that described by Watson,[1] which is carried out as follows: A piece of "gaslight" printing paper with a mat surface is embossed with the image of the coin by placing the front of the paper in contact with the coin and rubbing the back of the paper with a pointed instrument, such as may be made from a bone penholder. The embossed paper is placed face uppermost in a special printing frame and the exposure made by means of an electric lamp. The printing frame is of simple construction and is made easily from cardboard and binding tape: it consists essentially of (*a*) a rectangular piece of cardboard, about the size of a sheet of foolscap paper, across the centre of the narrow way of which is fixed at right-angles a second piece of cardboard (*b*), not so long as the first. The piece (*a*) is stood on a table long side up at an angle of about 45° facing the electric lamp to be used for developing, the shorter piece (*b*) acting as a support at the back. A rectangular opening is made in the centre of (*a*) just above where (*b*) takes off. This is for the light to pass through to the printing paper, which is laid on about the middle of the sloping surface of (*b*) and is held flat (which is essential) by means of two narrow slips of cardboard glued to (*b*), under which the edges of the printing paper are inserted. The printing paper is protected from any other direct light from the lamp, except that which passes through the slit, by the two sides of (*a*), as also the top, being provided with "blinkers," so that the extension of (*a*) above (*b*) has the appearance of an inverted tray. It is essential that the light that passes through the slit should fall upon the embossed printing paper at a low angle, so as to throw the minute markings on the paper into strong relief, each small depression and projection having both its illuminated and its shadow side, this unequal illumination being recorded by the sensitized surface of the printing paper in such a manner that a clear and perfect image of the coin is produced.

A little practice is required to make the rubbings and special care is needed not to move the paper during the operation. The rubbing-point should be smooth and polished and not sharp enough to damage the paper. The impressions made in the paper practically disappear during development and when mounted the finished print has a perfectly smooth surface.

All operations may be carried out after dark in a lighted room. The image is reversed, but if rephotographed this reversal may be corrected, or the print may be viewed by means of a mirror.

The other difficulty mentioned may be surmounted by dulling the surface of the coins, which is done by covering them with a thin layer of magnesium oxide. This is accomplished by fastening the coins with beeswax or plasticine

[1] H. J. Watson, *Conquest*, 1922, p. 49.

to a piece of cardboard that is held upside down, while underneath it a little magnesium ribbon is burned, the white oxide produced forming a thin uniform coating on the coins. A simpler and often quite satisfactory method is to apply to the face of the coin with the finger a very slight film of some white opaque material such as " toilet lanoline " tooth paste or zinc oxide ointment. The use of " grey powder " (mercury and chalk) suggested by one writer[1] for dusting the surface of coins to avoid reflection during photography is not recommended, since if the powder were rubbed on the coins, as might easily happen accidentally while they were being handled, the mercury would adhere to the coin and would change its appearance in a manner that might be very misleading if the coin were produced in Court.

Documents. Whenever possible all questioned documents should be photographed before they are examined in order that a record may be kept of their exact condition when received, and as a rule such photographs should be the same size as the document. Photographs of documents, however, are useful or necessary for other purposes. Thus by means of a microscopical examination of a document the expert may find definite evidence of alteration or erasure, but this can only be satisfactorily shown to others by means of enlarged photographs. Sometimes, too, the fact of alteration or erasure or the presence of traces of obliterated writing are visible, or are more clearly visible, only in a photograph.

In the case of an erasure where traces of original writing that it is desired to decipher, still remain, it will be found that a photograph taken by transmitted light sometimes will show greater detail than one taken by reflected light, and a simple and satisfactory method of taking this is by contact, employing a plate such as is used for lantern slides. If the document is small or one that can be folded without injury, the exposure is made best in an ordinary printing frame, the document taking the place of the usual negative and the photographic plate that of the printing paper. If the document is one that cannot be put in a frame, such for example as a register, the photographic plate is placed, with the sensitized face upwards, immediately beneath the writing it is desired to photograph, which is covered with a plate of clear glass to keep it flat. Artificial light is used for the exposure and frequently several trials are necessary before the correct time can be found. The negative gives a laterally reversed print if this is made by contact in the usual way, but by projection a correct print may be obtained. For purposes of examination, however, the negative is generally more satisfactory than the print, and if viewed from the film side, it shows the writing corrected. Prints, however, are necessary for attaching to the report or for presentation in Court.

If the writing on a document is indistinct, or if it is suspected that writing

[1] A. Evans, " Counterfeit Coins and Notes," *The Police Journal*, 7 (1934), p. 463.

has been effaced either by erasure or by chemical means, generally it is helpful to photograph it while exposed to the ultra-violet rays, this not only increasing the legibility of what may be indistinct, but revealing details otherwise invisible. If the writing has been obliterated by ink a photograph made with an infra-red sensitive plate will often reveal it.[1]

The photography of burnt documents has already been described.[2]

Enlarged photographs frequently are useful in the comparison of handwriting, and similarities and differences can be seen and studied best in this way. In all such cases, however, it should never be forgotten that the writing under examination is an enlargement, otherwise too much stress may be laid upon what in reality are very small points. In the identification or comparison of handwritings, photographic enlargements of the features upon which reliance is being placed to prove identity or non-identity are essential for demonstration purposes. The important letters or words to which the attention of the Court is directed specially should be cut out of enlarged photographs and mounted on stiff paper or cardboard in parallel columns, the genuine writing in one column, or on one sheet, and the questioned writing in another column or on another sheet.

As already pointed out in the chapter on Documents, photographs are very easily "faked," and therefore care is necessary before accepting them as of any evidential value. But even genuine photographs may be misleading; for instance, they do not distinguish between ink and pencil writing. In one case in my experience only a photograph of a certain document was available when I was first consulted, and neither the fact that the body of the document was written with copying pencil nor that certain corrections had been made with blacklead pencil was apparent in the photograph, which factors were important.

In the examination of forged banknotes and forged postage stamps, particularly the latter, photographic enlargements will be found helpful, as also for the comparison of inked seal impressions on documents.

A good and simple method of carrying out a comparison of two or more seal impressions in ink is to put the documents side by side in a photographic frame and, by means of an enlarging camera, to obtain enlarged images on a ground glass plate. Tracing cloth is then placed touching the glass plate and is held in position by a wooden framework or other device, and the enlarged images of the impressions are traced by hand with carbon ink directly on to the cloth. The tracings are then superimposed one on the other and examined by transmitted light. If, however, the case is one likely to be brought into Court, the best method is to make photographic enlargements, and from the negatives to prepare positives on glass that can be produced in Court and directly compared by superimposing one on the

[1] See pp. 254-255.

[2] See pp. 120-130.

other, as hand tracings are not satisfactory evidence. Since seal impressions frequently are made in coloured ink, it is necessary in such cases to use special panchromatic plates and light filters in order to obtain satisfactory photographs, and sometimes the best results are very poor or even useless.

As a corollary to the stereoscopic microscope advised for the examination of erasures and crossed lines, stereoscopic photomicrographs may be useful. These are strongly recommended by Osborn [1] for objects such as type, seals, seal impressions, coins and impressed designs of all kinds of which it is desired to show depth or solidity. Such photographs of course must be enlarged and then viewed by means of a stereoscope. For taking these photographs the ordinary stereoscopic camera cannot be used, since the two lenses cannot be brought sufficiently close together under the required magnification. Any good document camera, however, may be employed, two slightly different views being taken of the object. A simple method of doing this has been devised and described by Osborn.[1]

Marks on Bullets and Cartridge Cases. Enlarged photographs or photomicrographs, as the case may be, are essential for exhibition in Court and often are useful during the examination. Very satisfactory results may be obtained with a small first-class film camera and subsequent enlargement.

Robbery from Letters and Parcels. It is a useful precaution to photograph all envelopes and parcels immediately on receipt, and before they are dealt with, since the subsequent examination frequently necessitates making some change in their appearance, such for example as opening them in a new place or to a greater extent than was the case originally.

Stains and Marks. Photographs of stains and marks are most useful for attaching to a report or for exhibition in Court, as a much more accurate description can be conveyed by means of a photograph than by means of a written account. Whenever possible, therefore, stains and marks should be photographed before they are dealt with. In the case of small marks enlarged photographs should be made.

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X-RAYS.

Photography by means of X-rays frequently is very useful and, as already mentioned, it may be employed for determining the nature of the contents of closed packages, such as bombs, that it is not desirable to open until they

[1] A. S. Osborn, *Questioned Documents*, 1929, pp. 45–6.

have been proved to be harmless, and also there are many other ways in which it may be of service in criminal investigation ; for example, it may be made use of in fingerprint identification by rubbing the skin of the finger ends with powdered bismuth carbonate or red lead and then taking a radiograph, which shows the surface markings and the openings of the cutaneous glands in a very vivid manner. Radiography has been used by Baker [1] to determine the nature of compound bullets that it was not desired to cut open, and by Kaye, Laurie and Martin de Wild in the examination of oil paintings.[2]

Ultra-Violet Rays.

Ultra-violet rays are invisible rays that are present in sunlight beyond the violet end of the visible spectrum ; they may be produced artificially by passing a direct electric current through the vapour of mercury, which is done in a vessel of fused or vitrified silica,[3] since this material is transparent to ultra-violet rays, to which most of the ordinary commercial glasses are opaque. As rays other than ultra-violet rays are also present, these are cut off by means of a black glass screen of special composition which is permeable to ultra-violet rays.

Ultra-violet rays, although invisible, possess the power of exciting luminosity, in the form of a kind of glow, in many substances exposed to them, this luminosity varying in intensity and colour with the nature of the substance, that is to say, if certain materials are placed in the dark in the path of the invisible ultra-violet rays they become visible and coloured, the effect being termed fluorescence. Among the substances that show fluorescence are physiological fluids, certain chemicals, dyes, fats, animal and vegetable fibres, gums, minerals, oils, paper, resins and waxes, and not only do different materials behave differently, but also different kinds of the same material, some of which may thus be distinguished from other kinds of the same material. Examination by ultra-violet rays, therefore, constitutes a new and powerful weapon in the hands of the chemist. Examples of the value of the examination of materials when exposed to ultra-violet rays are given when dealing with the separate materials. Thus blood stains on a washed garment and also stains of many other kinds on fabrics that are invisible in ordinary light often show clearly when exposed to the ultra-violet rays ; erasures on documents are revealed ; partly faded writing and writing made with " invisible " ink become visible ; sealing wax and adhesives, such as gum, on documents that have been tampered with often may be differentiated from those used originally ; different papers fluoresce

[1] G. W. Baker, " Scientific Evidence Relating to Firearms, with Special Reference to a Recent Murder Trial," *Analyst*, 55 (1930), p. 740.
[2] A. Martin de Wild, *The Scientific Examination of Pictures*, pp. 92–104.
[3] The whole apparatus is in consequence frequently termed a quartz lamp.

differently ; forged cheques, forged banknotes and postage and fiscal stamps that have been forged or tampered with may be detected and glass fragments from different scources sometimes may be identified.

The fluorescent appearance of an object may be photographed, though this is not an easy matter, since the invisible ultra-violet rays act more energetically and more rapidly upon the photographic plate than do the fluorescing rays and, in order to eliminate the former as well as any other interfering rays present, filters must be employed. For this purpose glass screens have not been found very satisfactory, the best filters being thin layers of certain solutions, among which are triphenylmethane in absolute alcohol and cerium ammonium nitrate in water.

Although photographs of objects, as seen by ultra-violet rays constitute valuable evidence in Court and should be made, it has been found possible in several recent trials to instal an apparatus in Court and to give a practical demonstration,[1] [2] which is much more satisfactory. Even when this cannot be done in the Court itself, it should be possible in an adjoining room.

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INFRA-RED RAYS.

In addition to photography by ultra-violet rays, photography by infra-red rays, which are the invisible rays at the other end (the red end) of the visible spectrum often will be found useful. The technique is very simple, since no special apparatus is required beyond special photographic plates that have been rendered sensitive to the infra-red rays, a number of different makes of which are now on the market. These are used and developed in the same manner as ordinary plates, except that filters are required with the camera to cut off all ultra-violet, violet and blue rays and an exposure of from about

[1] *Analyst*, 1930, pp. 42–3.

[2] C. T. Symons, *Report of the Government Analyst, Ceylon, for* 1928, p. 15.

four to eight times that necessary for the usual photographic plates is needed and, for certain kinds of infra-red plates, also special developers, the details of which are supplied by the makers of the plates. The particular value of infra-red rays is for deciphering obliterated, charred and illegible documents, for the detection and deciphering of erasures and forgeries, for developing secret writing, for detecting stains on cloth, for differentiating colours of cloth and for distinguishing between different kinds of coloured inks, pencils, and pigments, and for revealing minute details of structure, as for example in hair. Professor Plotnikov has shown that a letter written with iron-gall ink and printed documents such as banknotes can be photographed inside a closed envelope by means of infra-red rays.

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CHAPTER XIII

POISONS.

THE Science of Poisons, or Toxicology as it is termed, comprises the origin, properties, chemical composition, physiological action detection and determination of poisons as also their antidotes, many of which matters are not chemical, while others are of little or no forensic importance. For the present purpose the subject will be limited to the chemical analysis required for the detection of the presence and the determination of the amount of those poisons most commonly employed for criminal purposes and by drug addicts. This is work for the expert only and should never be undertaken except by those having special experience, since the life or liberty of others often depend upon the results. The rough qualitative testing attempted sometimes in cases of suspected poisoning by those having little or no experience of chemical analysis, is most unwise, as at the best it uses up valuable material, while at the worst it may lead to a miscarriage of justice. Any qualitative testing for poisons should be carried out always with the same care and accuracy as in the case of quantitative work, and only by an experienced analyst. In this connexion the trial of Mrs. Maybrick [1] should be read, as also Taylor's evidence in the Smethhurst trial,[2] in both of which cases mistakes were made in testing for arsenic. In the former, a person with no experience of analysis attempted the Reinsch test, and naturally the results were neither satisfactory nor conclusive. In the latter, Taylor, when giving evidence in the preliminary examination before the magistrate, stated that arsenic was present in the material tested, whereas in the final trial he stated that his assistant had made a mistake, and that the arsenic found had come from the copper used in the test.

A chemist undertaking toxicological analysis, in justice to his work and to himself, must insist upon being supplied with the fullest information possible about all the cases in which he is consulted, and especially with information that may serve as a guide to the particular poison or class of poison to look for, otherwise he may waste both time and valuable material in searching for something that from the symptoms and circumstances of the case is not likely to be present, and when he does obtain evidence of the nature of the poison, there may not be sufficient of the sample left for a quantitative determination or even for a conclusive test.

In India the Government regulations state that the chemist shall

[1] H. B. Irving, *Trial of Mrs Maybrick*, 1912, pp. 104–6.
[2] W. Jago, *Forensic Chemistry and Chemical Evidence*, p. 150.

be supplied with the following information in all cases of suspected poisoning [1]:

(1) The interval between taking the last food or drink and
  (*a*) the first appearance of symptoms of poisoning and
  (*b*) death (if this has occurred).
(2) The nature of the first symptoms.
(3) Whether any of the following symptoms were present, and if so, which:
  (*a*) Vomiting and purging.
  (*b*) Deep sleep.
  (*c*) Tingling of the skin and throat.
  (*d*) Convulsions or twitchings of the muscles.
  (*e*) Delirium and clutching at imaginary objects.
(4) The nature of any other symptoms noticed.
(5) Whether any other person partook of the suspected food or drink and whether they also suffered from symptoms of poisoning.
(6) Any other information available likely to prove serviceable as a guide to the class of poison administered.

If a medical man has been in attendance in a case of poisoning or suspected poisoning, the symptoms and history of the case probably will indicate, if not the particular poison used, at all events the class to which the poison belongs. If a medical man has not been called in until immediately before or immediately after death, a search should be made in the room for the remains of food, drink and medicine, and for bottles, glasses and hypodermic syringes, any of which may provide evidence of the nature of the poison.

In the Crippen trial counsel for the defence tried to make capital out of the fact that the analyst knew that Crippen had bought hyoscine before " he tested for hyoscin and before he formed the opinion that he had found hyoscin," and referred to it as " unfortunate." This reflection upon the analyst was strongly condemned by counsel for the prosecution, and the judge when dealing with the point in his summing up said, " I do not think it is right to suggest that it is ' unfortunate ' that they knew that the man had bought hyoscin," and " I do not think if you are satisfied with Dr. Willcox's evidence that you ought to come to the conclusion that he was influenced one single bit by what he knew." [2]

Samples for Analysis. Samples of viscera necessarily will be taken by the medical man who conducts the post-mortem examination. Other samples, such as food or medicine, generally will be taken by the police or other investigating authority. In fatal cases of suspected poisoning all

[1] L. A. Waddell, *Lyon's Medical Jurisprudence for India*, 1914, p. 780.
[2] Filson Young, *The Trial of H. H. Crippen*, 1920, pp. 149, 160, 178.

the viscera and dejecta should be sent for analysis and should be packed as follows: (1) the entire stomach and contents in one receptacle; (2) the intestines with their contents in another receptacle; (3) the liver in a third receptacle; (4) the kidneys in a fourth receptacle; (5) the bladder and any urine in a fifth receptacle, and (6) the vomit, if any, in a sixth receptacle. If arsenic is suspected, portions of the hair, nails and muscle also should be sent. In cases of death from inhaling chloroform, the lungs, too, will be required. In non-fatal cases, the vomit, stomach washings, the urine passed during twenty-four hours and some fæces, each in a separate receptacle, should be sent for analysis.

In temperate climates no preservative of any sort should be added unless the article cannot be examined at once and cannot be placed in cold storage. In such an event, strong, plain spirit (rectified spirit) should be used, or in an emergency, when plain spirit is not available, denatured (methylated) spirit may be substituted. In hot countries, such as Egypt, spirit should always be used. A large sample of the spirit should be sent to the analyst as a control. In cases of suspected alcoholic poisoning, naturally spirit cannot be used, and if a preservative is necessary, a saturated solution of common salt should be employed. Formalin should never be used as a preservative, as in the case of alkaloid poisoning it is liable to cause decomposition even of such a relatively stable substance as strychnine, and in all cases it hardens the viscera and makes their extraction troublesome. The receptacles for the samples should be clean, wide-mouthed, white glass jars with glass stoppers, of about one litre capacity. These jars should not be filled more than two-thirds full, or probably they will burst owing to the pressure generated by the evolution of gases due to putrefaction. The stoppers of the jars should be greased with mineral oil or vaseline to prevent them sticking, and should be tied down with clean white cloth and sealed in such a manner that the jars cannot be opened without breaking the seals. Care should be taken that the seals are legible. The bottles should be packed carefully in a strong wooden box divided into compartments and articles belonging to different cases should not be packed in the same box.

Excellent rules for the guidance of those forwarding articles for analysis in suspected cases of poisoning are in use in India and may be found described in books dealing with Medical Jurisprudence in India.[1] [2]

Methods of Examination. The testing for poisons presents no great difficulty, but considerable skill and experience are required in separating poisons from other substances with which they may be mixed and in purifying them before the specific tests are applied.

[1] L. A. Waddell, *Lyon's Medical Jurisprudence for India*, 1914, pp. 776–86.
[2] P. Hehir and J. D. B. Gribble, *Outlines of Medical Jurisprudence for India*, 1908, pp. 645–56.

The articles it is usually necessary to test for poisons in connexion with crime or suspected crime are foods, liquors, medicines, vomit, urine, viscera and, in cases of the suspected doping of horses and dogs, saliva.[1] The methods employed for the testing are the same whatever the material examined may be and vary only with the kind of poison present, but the preparation previous to the testing differs with the nature of the material. It would be impracticable, however, to give all the possible variations in the methods of separating poisons from different materials, and also quite unnecessary, as the fundamental principles are familiar to most analysts and may be found described in the ordinary textbooks. It is equally unnecessary to give the tests for every poison, since of the large number known only a comparatively few are used for criminal purposes, and of those so used a large proportion are employed so rarely that they need not be considered in a general textbook. The methods and tests given, therefore, will be limited to those for the most usual poisons, and these will be described with particular reference to the examination of vomit, urine and viscera.

Preliminary Examination.

The first necessity is to make sure that all the apparatus used is chemically clean and that the reagents are absolutely pure, and this can be done only by the chemist personally superintending the cleaning of the former and personally testing the purity of the latter.

Glass apparatus may be cleaned thoroughly in the following manner: First wash in a 10 per cent. solution of sodium hydroxide; rinse with water; treat with a warm mixture of potassium dichromate and sulphuric acid (made by dissolving 500 grams of commercial dichromate in 6 litres of water and slowly pouring into this a kilogram (850 c.c.) of strong commercial sulphuric acid) and finally wash well with water.

Before beginning any examination, all solids should be weigned and all liquids measured. In the Pritchard poisoning case,[2] only portions of the viscera were sent for examination and the chemist who conducted the analysis was obliged to state in his report that he was unable to calculate the total quantity of poison present in the body as he had not been supplied with the weights of the entire organs.

(*a*) Vomit, Stomach Contents and Stomach Washings. These should be examined for reaction to litmus paper, colour and odour, and the sediment should be scrutinized carefully with a lens in order to detect any white or yellow arsenic, match heads, vegetable fragments such as seeds, leaves and

[1] The method of testing saliva has been described by G. D. Lander ("The Micro-Detection of Alkaloids," *Analyst*, **55** (1930), pp. 474–6). See also C. E. Morgan, Extraction of Minute Amounts of Morphine, *Industrial and Engineering Chemistry, Analytical Section*, **9** (1937), pp. 383–384.

[2] W. Roughead, *Trial of Dr Pritchard*, 1906, p. 186.

other portions of plants, opium or other poisonous material visibly present. Anything suspicious found should be separated, washed with water, dipped into alcohol, allowed to dry and carefully examined. Any food particles present also should be separated, washed and examined. Carbolic acid, chloral, chloroform, hydrocyanic acid or phosphorus, if present, frequently may be recognized by the smell.

(*b*) STOMACH AND INTESTINES. These should be slit open, if not already opened, and spread out separately in large white porcelain photographic dishes and examined carefully with a lens for general appearance, for remains of the last meal and for particles of poison, all solid material being separated, washed and examined.

Detailed Examination.

The methods used for the examination depend upon the nature of the poison present.

Poisons may be classified in many ways ; thus the medical man considers them with reference to their physiological action, while the analyst regards them according to the methods used for their extraction and isolation. Following the latter system, poisons may be divided into four main groups, namely :

(1) Volatile substances separated by distillation. Examples : carbolic acid, chloral, chloroform, hydrocyanic acid and phosphorus.

(2) Non-volatile substances separated by extraction with solvents. Examples : alkaloids and many poisonous synthetic drugs.

(3) Substances that remain when the organic matter has been destroyed by oxidation. Examples : compounds of arsenic, antimony, mercury, copper and lead.

(4) Substances requiring special methods of extraction. Examples : oxalic acid and oxalates.

Owing to the necessarily limited amount of material available, and to the act that any poison present is usually in very small amount, the greatest economy must always be practised in dealing with the samples, and, unless the symptoms indicate clearly the particular poison or class of poison used, it is recommended that each sample should be divided into at least three portions, one for distillation, a second for extraction with solvents, and the third to be reserved for control or reference purposes or for use in the possible event of an accident happening to one of the others. In this division no special provision is made for metallic poisons, but these may be tested for either in the residue from the distillation or in the residue from the extraction by solvents. A special portion of the samples must always be reserved for the search for alkaloids, since these can only be tested for in the original material before it has been subjected to any kind of treatment

owing to the fact that most of the alkaloids, except strychnine, are decomposed easily both by acids and alkalies, especially if heated.

If the material is solid, it should be divided finely, which is best done by means of a small mincing machine that of course must be scrupulously clean. The separate portions required for analysis then are weighed out. If the material is liquid, it should be stirred well and the separate portions measured.

The tests applied need not be many in number if they are chosen carefully. As far as possible the tests should be specific, and at least one confirmatory test should always be made. In the Chantrelle trial [1] the defence contended that the tests for meconic acid and morphine relied upon by the prosecution were not specific.

The various methods of separating and testing for poisons will be described in detail.

Volatile Poisons.

The search for volatile poisons manifestly should be proceeded with as soon as possible. Only the most important of these poisons will be considered, namely, carbolic acid, chloral, chloroform, hydrocyanic acid and phosphorus. The separation of the first four is performed by distillation in the following manner :

A wide-mouthed, round-bottomed flask of about a litre capacity is fitted with a two-holed cork and inlet and outlet tubes, the former being connected with a steam generator and the latter with a long glass condenser, the end of which is fitted with an adapter. The distillate is received in small test tubes surrounded by crushed ice, and if hydrocyanic acid or potassium or sodium cyanide is suspected the adapter should dip into a small quantity of a 2 per cent. solution of potassium hydroxide.

About 100 grams of stomach contents, or of minced viscera mixed with water to the consistence of thin gruel, are placed in the flask and are acidified with a few cubic centimetres of a 10 per cent. solution of tartaric acid. The flask is warmed and the steam supply connected up and steam passed slowly in. The distillate, which is collected in fractions of 8 to 10 c.c. at a time in numbered test tubes, is tested for carbolic acid, chloral, chloroform and hydrocyanic acid. If any of these substances is present it may have been recognized already by the smell in the stomach contents and frequently may be recognized by the characteristic smell of the distillate. Phosphorus, if present, also would be found in the distillate, but when this poison is suspected it is tested for better as described later.

Carbolic Acid. (Phenol.) Separate portions of the distillate are tested as follows :

1. Add Millon's reagent (made by dissolving a little mercury in its own

[1] A. D. Smith, *Trial of E. M. Chantrelle*, 1906, pp. 129–32.

weight of strong nitric acid (sp. gr. 1·4), diluting with twice its volume of water and decanting off for use the clear solution after settlement) and warm. If carbolic acid is present, a red coloration is produced. This, however, is not specific, as other substances beside carbolic acid give the same coloration.

2. Add bromine water until a permanent brown colour is obtained. A white or yellowish-white precipitate or turbidity indicates phenols.

3. Add a little dilute ammonia, then a few drops of a freshly prepared solution of bleaching powder or of sodium hypochlorite, and warm. If carbolic acid is present, a blue colour will be produced, which is turned red on the addition of acids.

4. Ferric chloride produces a bluish-violet colour with carbolic acid that is destroyed by mineral acids.

Sometimes traces of carbolic acid are produced in decomposing viscera and the presence of mere traces, therefore, is not of importance.

Chloral. This is ordinarily used in medicine in the form of hydrate and it is chloral hydrate, therefore, that is tested for. The following tests should be applied:

1. Add 1 or 2 drops of aniline and a few c.c. of alcoholic potassium hydroxide solution and heat gently. If chloral is present the characteristic and disagreeable smell of phenylisonitrile will be produced.

2. To 1 c.c. of the solution to be tested add 1 c.c. of a solution of resorcinol (5 per cent.) and 3 drops of sodium hydroxide solution (4 per cent.); boil actively and dilute with 10 c.c. of water. If chloral is present a pink colour will be produced.

3. Dissolve about 0·01 gram of beta-naphthol in 1 or 2 c.c. of potassium hydroxide solution (33 per cent.). Warm to 50° C. and add the solution to be tested. If chloral is present a blue colour will be produced that slowly turns green and finally brown.

None of the above tests is specific, all being given by chloroform, bromoform, iodoform and other similar compounds. The following test, however, although also not specfic, serves to distinguish chloral from chloroform.

4. Add a few drops of Nessler's solution and shake. In the presence of chloral a red precipitate will be produced, which turns to a dirty yellowish-green.

If the amount of chloral hydrate is not too small, a portion may be extracted from the distillate by means of ether, by the careful evaporation of which it may be obtained in the crystalline form and the melting point determined.

Chloroform. This gives the phenylisonitrile, resorcinol and beta-naphthol tests already described when dealing with chloral. The following, however, is a specific test:

Transfer the distillate to a small flask provided with an inlet tube reaching

to the bottom of the flask and an outlet tube of hard glass or silica bent horizontally. Pass air into the flask, either by pressure or by suction, and warm the flask. Strongly heat the outlet tube. If chloroform is present it will be given off from the solution and decomposed in the heated tube, with the formation of free chlorine and hydrochloric acid. The former may be recognised by its turning iodide of starch paper blue [1] and the latter by the reddening of blue litmus paper and by the formation of a white precipitate (silver chloride) insoluble in nitric acid when it is passed into a solution of silver nitrate.

Hydrocyanic Acid (Prussic Acid). Hydrocyanic acid, if present, either in the free state or in combination as potassium or sodium cyanide, will be found in the distillate, but mercuric cyanide, unless present in considerable amount, does not yield hydrocyanic acid when distilled with tartaric acid and, therefore, may be missed, unless special search is made. Mercuric cyanide, however, is partly decomposed by proteins [2] and hydrocyanic acid in the distillate therefore occasionally may be derived from mercuric cyanide and hence mercury should be tested for in the distillate whenever hydrocyanic acid is found. To detect mercuric cyanide, add to the distillate a few c.c. of a freshly prepared solution of sulphuretted hydrogen, which decomposes mercuric cyanide, liberating hydrocyanic acid ; continue the distillation and test for hydrocyanic acid.

The non-poisonous ferrocyanides, ferricyanides and thiocyanates also yield hydrocyanic acid when distilled with tartaric acid and therefore if hydrocyanic acid is found in the distillate, the original material should be tested for the double cyanides and for thiocyanates. This may be done by extracting a little of the material with a small quantity of water, filtering, concentrating the filtrate by evaporation, acidifying with dilute hydrochloric acid and to one portion adding a few drops of ferric chloride solution, when ferrocyanide, if present, will be shown by the formation of Prussian blue. To a second portion add a few drops of ferrous sulphate solution when a blue precipitate will be formed if ferricyanide is present. Under the conditions of the test there will be almost certainly a mixture of ferrocyanide and ferricyanide present. To a third portion of the acidified filtrate add a few drops of ferric chloride solution when a blood-red colour, insoluble in mercuric chloride, will be formed if a thiocyanate is present.

The tests for hydrocyanic acid are as follows :

1. Add to a portion of the distillate that has been collected in potassium hydroxide, two drops of dilute ferrous sulphate, or ferrous ammomium sulphate, solution and one drop of ferric chloride solution ; shake well,

[1] This must be looked for carefully as the coloration is very transient.

[2] R. Fabre and J. Jossett, " Contribution to the Study of the Toxicity of Mercuric Cyanide," *J. Pharm. Chem.*, **28** (1923), pp. 81–89 ; *Analyst*, **48** (1923), p. 565.

allow to stand two minutes, warm gently and acidify with dilute hydrochloric acid. If much hydrocyanic acid is present, Prussian blue will be formed, but if traces only are present only a faint bluish-green coloration may be produced, yielding however blue particles on standing, which are easily visible on the filter paper if the liquid is filtered.

2. To a second portion of the distillate that has been collected in potassium hydroxide, add a little yellow ammonium sulphide solution and evaporate to dryness on a water bath. Dissolve the residue in a small amount of water and acidify with dilute hydrochloric acid. Filter to remove sulphur and add a drop of ferric chloride solution. If hydrocyanic acid is present a blood-red colour will be produced.

To test for cyanides in presence of ferrocyanides, ferricyanides or thiocyanates, make the solution alkaline with caustic soda, warm to 50° C.–60° C. and pass in a stream of carbon dioxide, which liberates hydrocyanic acid that may be tested for in the distillate if the mixture is distilled.[1]

Phosphorus. When employed for criminal purposes, phosphorus is generally obtained either from lucifer matches or from rat poison, in both of which it is present in the yellow or poisonous form. The best preliminary test for phosphorus is that proposed by Scherer, which depends upon the facts that phosphorus is readily volatile and that its vapour blackens silver nitrate. The test is carried out as follows: Place the suspected substance in a finely divided condition in a small flask, cover with water and add a sulphuric acid solution of 2 to 3 grams of cadmium sulphate in order to fix any sulphuretted hydrogen formed, which otherwise also would blacken the silver nitrate. Close with a cork having a groove cut in one side and from the cork suspend two test papers, one being moistened with 5 per cent. silver nitrate solution and the other with a solution made by adding sodium hydroxide solution to 5 per cent. lead acetate solution until the precipitate that first forms is redissolved. The flask is warmed gently on the water bath. If the silver nitrate paper does not darken, phosphorus is absent. If both papers darken, the test is inconclusive. If only the silver nitrate paper darkens, phosphorus may be present but needs confirmation. The test must be carried out in the dark or the silver nitrate paper will blacken in the absence of phosphorus. The best confirmatory test is that proposed by Mitscherlich, which consists in the distillation of the suspected substance in the dark after acidifying with sulphuric acid, the vapour in the condenser generally being luminous if phosphorus is present.[2] Certain substances, however, among which are alcohol, ether and turpentine, may prevent phosphorescence.

[1] For the detection of inhaled hydrocyanic acid see G. D. Elsdon, J. R. Stubbs and G. Roche Lynch, *Analyst*, 62 (1937), pp. 540–541.

[2] Phosphorus sesquisulphide (P_4S_3), which sometimes is used for safety matches, would give the same reaction.

Phosphorus imparts a strong odour to the distillate. To confirm, evaporate a portion of the distillate to dryness with a little fuming nitric acid. Dissolve the residue in about 3 c.c. of water, add a few drops of strong nitric acid and an equal volume of ammonium molybdate solution and allow to stand at a temperature of about 40° C. A yellow precipitate indicates phosphorus.

Poisons Extracted with Solvents

This class of poisons includes (*a*) alkaloids, the principal of which are aconitine, cocaine, hyoscyamine, hyoscine, morphine, morphine derivatives, and strychnine, and (*b*) poisonous synthetic drugs, the most important of which are acetanilide, antipyrine, phenacetin, sulphonal and veronal. The alkaloids generally are employed medicinally in the form of compounds, either simple salts produced by the combination with an acid or more complex bodies such as ethers [1] and esters.[2] Thus aconitine is used usually as nitrate ; cocaine as hydrochloride ; hyoscyamine as sulphate ; hyoscine as hydrobromide ; morphine as hydrochloride, tartrate, diacetyl-morphine (heroin), ethyl-morphine hydrochloride (dionine), or in the form of some preparation of opium, such as laudanum, and strychnine as hydrochloride. It is these compounds, therefore, that are employed ordinarily for criminal purposes and by drug addicts, but in whatever form originally present, except in the case of ethers and esters, it is the alkaloid that is extracted finally and tested.

The principal solvents employed in chemico-legal practice are alcohol, chloroform, ether-ethyl acetate mixture and ether-chloroform mixture. The method adopted for the systematic separation of alkaloids and poisonous synthetic drugs, which is known as the Stas-Otto process, is briefly as follows :

(*a*) Extraction of the viscera with alcohol, which dissolves not only the alkaloids and synthetic drugs, but also albumin, fat, colouring matter and other substances which latter would interfere with subsequent tests, and which therefore must be removed.

(*b*) Removal of the alcohol either by evaporation or by distillation under reduced pressure, and extraction of the residue with water faintly acidulated with sulphuric acid. The acid converts the alkaloids into acid salts, which are soluble in water. The water, however, only partly dissolves some of the synthetic drugs mentioned, several of them being only slightly soluble in cold water, and these therefore must be extracted separately from the residue.

(*c*) Purification of the acid water solution with various solvents (those

[1] Example, dionine, which is ethyl-morphine hydrochloride.

[2] Example, heroin, which is diacetyl-morphine, frequently employed in the form of the hydrochloride.

usually employed being petroleum ether, ether, chloroform, and mixed ether and ethyl-acetate), which, in addition to taking out impurities, may extract also certain poisonous synthetic drugs. Although these solvents are the ones finally employed to extract the alkaloids, here they do not dissolve them because they are present in the form of acid salts, but merely separate various impurities, which if left in the solution would be extracted eventually with the alkaloids and would contaminate them.

(*d*) Making the water solution alkaline in order to liberate the alkaloids from their salts and extracting the alkaloids with chloroform and ether-ethyl acetate.

(*e*) Purification, weighing and testing of the alkaloids and synthetic drugs extracted.

The process, the details of which vary somewhat with different workers, is essentially as follows [1]:

Preparation of Material. Solids, such as viscera, are minced finely and a weighed portion taken, which should be as large as possible having regard to other tests and to the keeping of a reserve portion of the material for contingencies. Fluids like vomit are measured and almost neutralized with sodium bicarbonate solution, care being taken that they are never made alkaline but always are left faintly acid, after which they are evaporated to a syrupy consistency. The evaporation is carried out at a temperature not exceeding 45° C. and is expedited by gently blowing hot air on to the surface of the liquid either from a pressure pump or from an electric blower. This also acts as a corrective of any tendency to over-heating, and prevents the formation of a scum that would retard evaporation.

First Extraction with Alcohol. Put the material into a large flask and add twice the weight of 95 per cent. alcohol made faintly acid with acetic acid, warm to about 45° C., cork the flask, shake well from time to time with occasional warming and finally allow to digest for twenty-four hours. Decant the liquid through several layers of muslin placed in a large funnel, transfer the solid matter to the filter by means of a little alcohol, and free the residue from as much liquid as possible by squeezing it in the muslin. Digest the solid matter with the muslin for a further twenty-four hours with fresh alcohol made faintly acid as before with acetic acid. Again decant the liquid through fresh muslin and again squeeze the solid residue, and finally wash it well with alcohol. If the second extract is highly coloured, a third and similar extraction is made. The solid residue is reserved for the search for metallic poisons.

[1] The method given is that elaborated by Mr W. M. Colles, for use in Egypt. See also F. Bamford, *Poisons: Their Isolation and Identification*, pp. 239–250.

The alcoholic extracts, which are never clear, are mixed together, acidified faintly with acetic acid and warmed quickly on a water bath to 70° C. to coagulate as much albumin as possible. Cool under the tap and filter through muslin. The filtration often is very troublesome, and it may be necessary to allow the liquid to settle overnight in a tall cylinder and to decant the following morning. The solid matter, after well washing with alcohol, which is separated either by filtration or decantation, is added to the previous residue and the washings are added to the main liquid.

Evaporation of the First Alcoholic Extracts. The mixed alcoholic extracts and washings are transferred to a large shallow porcelain basin, treated with sodium bicarbonate solution until only faintly acid, and then are evaporated at a temperature not exceeding 45° C., using a stream of hot air gently blowing on to the surface of the liquid to hasten evaporation.[1] As the liquid concentrates it is necessary to watch it carefully and to add a little sodium bicarbonate solution from time to time in order to keep the solution only just acid. Oil and fat will separate out and are filtered off, washed with alcohol and rejected, the washings being added to the solution. The evaporation is continued until the liquid is syrupy.

Second Extraction with Alcohol. The syrupy extract is covered with absolute alcohol and allowed to stand three minutes. The alcohol is poured off and the process repeated several times. In about fifteen minutes the surface changes to a lighter colour and becomes granular. The mass, which is still brown and sticky internally, is cut across in all directions with a spatula, stirring, however, being avoided, and drenched repeatedly with absolute alcohol, which is renewed every five minutes. All lumps must be broken up with the spatula so that the inner sticky portions are brought into contact with the alcohol. In about an hour the whole mass disintegrates into a granular powder. This is transferred to a glass or porcelain mortar and ground up with absolute alcohol until no more colour is extracted. The process must be carried out continuously, as if the granular powder is left exposed it absorbs water and reverts to the sticky condition. Throughout the whole operation the mixture must be faintly acid, a drop of dilute acetic acid being added to the alcohol if necessary. The residue is rejected.

Evaporation of the Second Alcohol Extracts. The united absolute alcohol extracts are made nearly neutral and filtered. The residue is washed with a little absolute alcohol and rejected, and the washings are added to the filtrate, which is evaporated[1] until all the alcohol is expelled and the liquid becomes syrupy.

Extraction with Water. The syrupy mass is treated with a small quantity of water and well stirred. The mixture should be faintly acid. If an emulsion

[1] Or distilled under reduced pressure.

forms, more water is added and the mixture warmed to 40° C. After thorough digestion with the water, the mixture is filtered and the residue well washed with water, the washings being added to the main solution. The residue, which consists chiefly of fat, will contain also some part of any substances originally present that are not very soluble in cold acidulated water, such as acetanilide, phenacetine, sulphonal and veronal. This residue therefore is reserved for further examination. The filtrate contains all alkaloids and other substances soluble in cold acidulated water.

PRELIMINARY TESTS WITH WATER EXTRACT.

At this stage a few preliminary tests sometimes are useful, but before describing them a general caution may be given, namely, that as the amount of poison present is always very small, the tests made should be chosen with discrimination and carried out with care, as only a few tests can be applied and as a rule there is not sufficient material to allow of a test being repeated.

Taste. A tingling and numbing sensation may indicate aconitine: a bitter taste with numbing may indicate cocaine: an intensely bitter taste may indicate strychnine.

Physiological Tests. (*a*) A few drops are made neutral and put into the eye of a cat: mydriasis indicates atropine, hyoscine or hyoscyamine.

(*b*) A quarter of a cubic centimetre of the extract is injected into the dorsal lymph sac of a frog to ascertain whether it is toxic and whether it produces convulsions, which latter may indicate strychnine.

(*c*) To a few drops of the solution in a small white dish or on a white porcelain tile add one drop of ferric chloride solution. A red coloration indicates meconic acid, which denotes opium. This coloration is distinguished from a somewhat similar one produced by acetates and thiocyanates as follows: (*a*) The colour of ferric acetate is destroyed at once by dilute hydrochloric acid, while ferric meconate is not decolorized until strongly acidified and (*b*) ferric thiocyanate is decolorized by mercuric chloride, while ferric meconate is not affected.

Opium. If opium is present in quantity, the ferric meconate reaction described above will be distinct. If the test is not distinct and yet opium is suspected, meconic acid, if present, may be separated and tested for as follows: To the whole of the remaining acid aqueous extract a 10 per cent. solution of basic lead acetate solution is added drop by drop until no further precipitate is produced. The mixture is warmed to 50° C. and allowed to settle. The precipitate is filtered off and washed once with water, the washings being added to the filtrate, which contains any alkaloids and synthetic drugs present, and which is reserved for further treatment. A hole is made in the apex of the filter paper and the residue washed into a test tube with as

little water as possible. Sulphuretted hydrogen is passed through the liquid to saturation: this decomposes the lead meconate forming lead sulphide and liberating meconic acid. The lead sulphide is filtered off, washed and rejected and the filtrate evaporated on the water bath at a low temperature to a volume of about 1 or 2 c.c. A drop of dilute hydrochloric acid is added, followed by a drop of ferric chloride solution. Any red coloration formed is distinguished in the manner already described from the similar colour produced by acetates and thiocyanates. A positive result is conclusive of opium.

It is usually preferable, however, to test for meconic acid in the residual aqueous liquid after extraction by the various solvents, which not only saves time, but avoids possible loss of alkaloids consequent on the additional manipulation of the solution containing them. Bamford [1] adopts the following process: The residual liquid, after any alkaloids or synthetic drugs present have been extracted, is tested with litmus paper. If acid, it is made alkaline by the addition of magnesium oxide, boiled with animal charcoal (in place of treatment with lead acetate), both to decolorize it and to reduce the bulk, filtered and tested for meconic acid as already described.

The tests for morphine will be given later.

Purification of the Water Extract. If meconic acid has been tested for, this solution will contain lead acetate, to separate which it is treated with sulphuretted hydrogen, the lead sulphide filtered off and the filtrate freed from sulphuretted hydrogen by evaporating it to small bulk in a shallow dish at a temperature of 50° C., a faint acid reaction being maintained throughout. The final residue is diluted with water. This solution, or the original water solution if meconic acid has not been tested for, is acidified with a drop of dilute sulphuric acid [2] (which converts any alkaloids present into sulphates) transferred to a small separating funnel and agitated by gentle rotation [3] successively with the following solvents, which are afterwards separated in the usual manner: (*a*) 20 c.c. of petroleum ether, (*b*) 20 c.c. of ether, (*c*) 15 c.c. of chloroform, (*d*) 15 c.c. of chloroform. The ether and chloroform extracts are mixed and washed by agitation with 5 c.c. of water made faintly acid with sulphuric acid,[2] the washings being returned to the main water solution. The mixed extracts are transferred to a small basin and allowed to evaporate to dryness by simple exposure without heat. The petroleum ether extract consists chiefly of fat, and need not further be considered. The mixed ether and chloroform extract will not as a rule contain any alkaloids, the acid salts of the alkaloids, unlike the alkaloids themselves, being practically insoluble in these solvents, but may

[1] Formerly Director, Medico-Legal Laboratory, Cairo.

[2] The acid used must be sulphuric acid.

[3] Violent agitation is liable to produce an emulsion, which is far easier prevented than removed.

contain acetanilide, antipyrine, phenacetine, sulphonal and veronal. The purification and testing of this extract will be described later.

The acid aqueous liquid after extraction with the solvents mentioned, and which still contains all the alkaloids, is warmed gently to drive off dissolved ether.

SEPARATION OF ALKALOIDS. The method used for separating the alkaloids depends upon (*a*) whether morphine only is being looked for, (*b*) whether morphine together with other alkaloids may be present, or (*c*) whether morphine may be excluded.

Morphine only Present. If morphine is the only alkaloid that need be searched for, the acid liquid is transferred to a separating funnel and extracted with a mixture of 20 c.c. of equal volumes of ether and ethyl acetate.[1] The solvent is separated and washed with 5 c.c. of water slightly acidified with sulphuric acid, the washings being added to the main solution. This treatment does not dissolve morphine, the acid salt of which is insoluble in the solvent used, but removes various impurities that would interfere with the subsequent tests.

The acid liquid is made alkaline with sodium bicarbonate, which liberates morphine from its acid salt, and is extracted with mixed ether and ethyl acetate, employed exactly as before, but the solvent now dissolves the alkaloid. At least three separate extractions should be made. The extract is purified and tested as described later.

Morphine and other Alkaloids Present. The acid solution is treated with mixed ether and ethyl acetate, as previously described, in order to remove impurities. It is then warmed to 40° C. to drive off any ether present, filtered if necessary, placed in a separating funnel, 20 c.c. of chloroform added and a piece of litmus paper. Very dilute sodium hydroxide solution is added drop by drop with gentle agitation until the litmus turns blue, when the funnel is corked and shaken. The alkali liberates the alkaloids from their acid salts and dissolves the morphine, which behaves differently to other alkaloids. The chloroform is separated and the extraction repeated twice with 10 c.c. more chloroform each time. The chloroform extracts, which contain all the alkaloids except morphine, are mixed and reserved for subsequent purification and testing as described later. The morphine remains in the solution and is extracted with mixed ether and ethyl acetate as described and the extract purified and tested as given later. Sometimes a mixture of equal parts of chloroform and ether is used in place of chloroform, but aconitine, hyoscyamine and strychnine are more soluble in

[1] As ethyl acetate frequently is acid it should be shaken before use with dilute sodium carbonate solution, which is separated and rejected. Roche Lynch says that ethyl acetate is possibly not so efficient as amyl acetate or alcohol-chloroform, but that it is more selective. (G. Roche Lynch, *Analyst*, 63 (1938), p. 245.)

chloroform, which therefore is preferable. Marden and Elliott show that three extractions each with 10 c.c. of chloroform will extract more than 99·9 per cent. of the aconitine from 50 c.c. of an ammoniacal aqueous solution, while six similar washings with ether only extract 99 per cent.[1]

Morphine Absent. The acid solution is made alkaline with sodium carbonate solution and extracted with chloroform as described above. The extract contains all the alkaloids, and is purified and tested as described later.

NOTE ON EXTRACTION WITH SOLVENTS. It is a well-known fact that may be proved mathematically and demonstrated chemically, that if a precipitate on a filter paper is washed twice with a given quantity of water any soluble salts present are reduced in amount more than if the precipitate be washed once with double the quantity of water. In the same way when a liquid is being extracted with a solvent, the best results are obtained by using a large number of extractions with a small volume of solvent each time rather than a small number of extractions with a large volume of solvent.

Purification of the Final Extracts. These extracts, which are too impure for the specific tests for the poisons to be applied, consist of (*a*) the ether-chloroform extract from the acidulated water, which may contain acetanilide, antipyrine, phenacetine, sulphonal and veronal ; (*b*) the chloroform extract from the alkaline water solution containing any alkaloids except morphine, and (*c*) the ether-ethyl acetate extract containing morphine. These extracts are purified as follows :

ETHER-CHLOROFORM EXTRACT. The various synthetic drugs mentioned, being only slightly soluble in cold acidulated water, are partly left behind in the residue from the absolute alcohol when this is treated with water. This residue should be extracted with hot water, filtered hot and extracted when cold (without further filtration if a turbidity appears) with chloroform. This chloroform extract is added to the ether-chloroform extract from the acidulated water and both are purified together. This purification is difficult, and may best be carried out by allowing the solution first to evaporate to dryness spontaneously, then to stand in a warm place exposed to the air overnight (which renders insoluble a certain proportion of the impurities present [2]), afterwards separating the fat by means of petroleum ether and extracting the residue with hot alcohol which is evaporated spontaneously in a small basin. The residue is again extracted with hot alcohol, filtered and the filter paper washed with a few c.c. of hot alcohol ; again evaporated to dryness spontaneously in a small weighed glass basin, weighed and tested as described later.

[1] J. W. Marden and V. Elliott, " A Study of the Methods for Extractions by Means of Immiscible Solvents from the Point of View of the Distribution Coefficients," *Industrial and Engineering Chemistry*, 1914, pp. 315–20, 928–34.

[2] F. Peterson, W. S. Haines, and R. W. Webster, *Legal Medicine* and *Toxicology*, 2 (1923), p. 62.

CHLOROFORM EXTRACT. This is placed in a small separating funnel and 10 c.c. of water acidified with a drop of sulphuric acid are added. When the mixture is shaken the alkaloids combine with the acid to form salts which leave the chloroform and dissolve in the acid water. The impurities largely remain in the chloroform which is separated from the water, shaken with a further 10 c.c. of acidified water and again separated and finally rejected. The two lots of acid water are mixed and contain the alkaloids in a fairly pure state. If the solution is coloured brown, it may be purified further by shaking with petroleum ether, ether or ethyl acetate. The acid water solution is transferred to a separating funnel with 10 c.c. of chloroform and a solution of sodium carbonate is added drop by drop until the liquid is distinctly alkaline. The sodium carbonate liberates the alkaloids from their salts, and on shaking the solution the alkaloids dissolve in the chloroform. The chloroform is run off and the alkaline liquid left in the separating funnel is shaken at least three times with 5 c.c. of chloroform each time, the various lots of chloroform being mixed. The chloroform is filtered through a small filter paper moistened with chloroform in order to separate any small amount of water present, and the filter paper is washed with a few cubic centimetres of chloroform. The solution is transferred to a small glass basin and allowed first to evaporate to dryness spontaneously, then allowed to stand overnight in a warm place exposed to the air (which renders insoluble a certain proportion of the impurities present [1]), extracted with hot alcohol and filtered into a small weighed glass basin, the filter paper washed with a few c.c. of hot alcohol and the alcohol extract and washings allowed to evaporate to dryness spontaneously and weighed. The residue in the basin appears as a brown ring of varnish-like matter on the side of the dish, while at the bottom is a brownish deposit or amorphous powder which is purer than the ring round the sides. This may be purified further if necessary by recrystallization from warm alcohol and the final residue again weighed and tested as described later.

ETHER-ETHYL ACETATE EXTRACT. This is purified in the same manner as the chloroform extract except that ether-ethyl acetate mixture is used in place of chloroform and sodium bicarbonate instead of sodium carbonate. The residue is weighed and tested as described later.

Chiefly on account of the lengthy nature of the Stas-Otto process for the extraction of alkaloids, several alternative methods have been proposed, of which those of Fabre and of Daubney and Nickolls are the most important.

Fabre [2] suggests proteolysis by means of pancreatin. Daubney and

[1] F. Peterson, W. S. Haines, and R. W. Webster, *Legal Medicine and Toxicology*, **2** (1923), p. 62.

[2] R. Fabre, *Compt. rend.*, **180** (1925), pp. 966–967 ; *Analyst*, 1925, p. 247.

Nickolls[1] advocate (*a*) freezing the viscera before mincing; (*b*) avoiding the use of alcohol for extraction except in the case of morphine, and (*c*) avoiding the use of lead salts for the purification of the alkaloidal extracts.

Bamford,[2] whose experience of toxicological analysis was very considerable and extended over many years, replying to Daubney and Nickolls, points out that freezing is very costly and is impracticable when large numbers of samples have to be examined simultaneously; that viscera often reach the laboratory preserved in alcohol and therefore that partial extraction of the alkaloids has already commenced, and that lead salts have been extensively used by him with most satisfactory results.

Tests for Alkaloids.

General Tests. Before applying any special tests for alkaloids, general tests are used in order to ascertain whether an alkaloid is present or not. These tests are not specific, and a precipitate may be obtained even if an alkaloid is not present, as many substances besides alkaloids give precipitates with the reagents. A positive result therefore needs confirmation. If no precipitate is obtained, alkaloids are absent. A very slight precipitate usually means a negative case unless some very sensitive and specific confirmatory test, such as the taste test for aconitine, is applicable.

As the quantities both of solution available and of reagents to be used for each test are very minute, consisting of a drop or two at the most, capillary pipettes or very fine glass rods must be employed for taking up the liquids, and the tests must be carried out in small watch glasses. For the preliminary tests the material from the brown ring on the sides of the basin is used, the purer residue at the bottom of the basin being reserved for confirmatory tests. A little of the brown ring is removed, dissolved in a few drops of chloroform and drops of the solution placed on a number of small watch glasses and allowed to dry, and the residue on each is then tested as follows:

(1) The best general test is with sodium phosphomolybdate (10 per cent. solution in 10 per cent. nitric acid). This produces with alkaloids a yellow amorphous precipitate that usually turns blue on standing. To apply the test the material to be tested is dissolved in a drop of dilute nitric acid. Ammonium salts give a similar precipitate.

(2) The smallest possible drop of dilute sulphuric acid is added, and then iodine solution (1 gram iodine : 2 grams potassium iodide and 50 c.c. water). If alkaloids are present, a chocolate-coloured precipitate is produced.

[1] C. G. Daubney and L. C. Nickolls, "An Investigation into the Methods of Toxicological Analysis of Viscera," *Analyst*, **62** (1937), pp. 851–859; **63** (1938), pp. 560–566.

[2] F. Bamford, (*a*) *Analyst*, **63** (1938), pp. 645–649; (*b*) *Poisons: their Isolation and Identification*, 1940, p. 250.

(3) The smallest possible drop of dilute sulphuric acid is added and then a drop of Mayer's reagent (made by adding a solution of potassium iodide to one of mercuric chloride until the red precipitate first formed is just dissolved). If alkaloids are present, a white or yellowish precipitate is produced.

Special Tests. The most satisfactory test for an alkaloid would be the preparation, purification and subsequent identification of a definite derivative or series of derivatives, as is done in the case of new organic compounds, but unfortunately the amount of material available is never sufficient for this and the chemist, therefore, is forced to apply chemical colour tests, though they are less satisfactory and sometimes may even be misleading if the alkaloid is not pure. Reliance, however, should never be placed upon the result of any one test, but several confirmatory tests should be made, and the reaction obtained should always be compared with that produced by testing similarly a known pure specimen of the suspected alkaloid.

One of the most characteristic properties of alkaloids is that of forming insoluble crystalline compounds with various reagents, among which gold chloride, picric acid, mercuric chloride (for heroin and dionine) and Marmé's reagent (for morphine and codeine) may specially be mentioned.[1] [2] [3] [4] [5] [6] The alkaloid or alkaloidal residue to be tested is dissolved if possible in water, but if not completely soluble, sufficient dilute hydrochloric acid (10 per cent.) is added drop by drop until solution is effected. All solutions to be tested should be as nearly neutral as possible, since free acid may interfere with the test. Gold chloride and mercuric chloride are used in 5 per cent. aqueous solution : picric acid is used in saturated aqueous solution. Marmé's reagent is prepared as follows : cadmium iodide, 3 grams ; potassium iodide, 6 grams ; water, 18 c.c. The precipitates should be recrystallized from alcohol whenever possible. The particular alkaloid present may be recognized by the crystalline form of the compound produced when seen under the microscope and also by its melting point, if there is sufficient of the precipitate to allow of this determination being made. This test, however, like those previously referred to, is generally inapplicable and for the same reason, namely the small amount of material available.

[1] C. H. Stephenson, *Some Micro-Chemical Tests for Alkaloids*, 1921.

[2] B. E. Nelson and H. A. Leonard, " Identification of Alkaloids under the Microscope from the Form of their Picrate Crystals," *Journ. Amer. Chem. Soc.*, 1922, pp. 369–73.

[3] E. B. Putt, " Microchemical Tests for the Identification of Some of the Alkaloids," *Ind. and Eng. Chem.*, **4** (1912), pp. 508–12.

[4] C. K. Glycart, " Report on Microchemical Methods of Analysis," *Journ. Association of Official Agric. Chemists*, **10** (1927), pp. 370–74 ; **11** (1928), pp. 353–5.

[5] G. D. Williams and C. C. Fulton, " Microscopic Identification of Heroin," *Amer. J. Pharm.*, 1933, **105**, pp. 436–440 ; *Analyst*, **58** (1933), p. 766.

[6] C. C. Fulton and J. B. Dalton, " Micro-crystal Identification Tests for Morphine, Heroin, Dilaudid and Cocaine," *Journal of Criminal Law and Criminology*, **32** (1941), pp. 358–365.

Dr. (later Sir) W. H. Willcox was questioned in the Crippen trial about the value of the melting point test for alkaloids and pointed out that "the melting-point test is a valuable one, but you can never get enough . . . to apply the test."[1] There are now on the market several different forms of electrically-heated microscope stages such as the Reichert melting point apparatus and others,[2 3] by means of which melting point determinations may be made with a much smaller quantity of material than was possible formerly. The alkaloids as extracted, however, are generally in too impure a condition to give useful results.

Dobbie[4] and other workers[5] have shown that in general the alkaloids have very characteristic absorption spectra and that a quantity as small as one five-hundredth of a grain (0·03 mgm.) of morphine gives a clearly defined spectrum. "The spectroscope serves, not only for the detection, but for the estimation of alkaloids; by comparing the spectrum obtained with an unknown quantity of an alkaloid with a series of spectra obtained by photographing known quantities of the same alkaloid, it is possible to make quantitative determinations of a high degree of accuracy."[4] As Dobbie points out, one advantage of the spectroscopic determination is that the material is not destroyed and may be used again for the chemical examination, and another advantage is that a permanent photographic record is obtained for future reference. The spectroscopic method, however, requires considerable experience and an expensive apparatus that is not usually available.

Dilute solutions of certain alkaloids and synthetic drugs when absorbed by filter paper and examined by means of the ultra-violet rays give a distinctive fluorescence, sometimes even though the solution is impure and coloured. Aspirin, heroin, morphine and novocaine are all stated to yield characteristic results. This method has not yet been fully developed, but holds out promise of usefulness.

The chemical tests for the separate alkaloids may now be described.[6]

ACONITINE.[7] There is no good chemical test. The most satisfactory test is the physiological one, which consists in the characteristic tingling and numbing sensation produced when the smallest drop of a solution containing aconitine is applied to the tongue or lips. Veratrine also produces tingling,

[1] F. Young, *The Trial of H. H. Crippen*, 1920, pp. 72–3.
[2] M. P. Cram, "Determination of Melting Points with the Aid of the Microscope," *Journ. Amer. Chem. Soc.*, **34** (1912), pp. 954–6.
[3] E. M. Chamot, *Handbook of Chemical Microscopy*.
[4] J. J. Dobbie, "The Spectroscope in Organic Chemistry," *Royal Institution Lecture*, 4th April 1913.
[5] M. de Laet, "Spectrographic Identification of Alkaloids," *Chemical Abstracts*, **20** (1926), p. 1130.
[6] See also F. Bamford, *Poisons: Their Isolation and Identification*, pp. 255–283.
[7] General Reference: F. H. Carr, "Aconite Alkaloids," *Allen's Commercial Organic Analysis*, **7** (1929), pp. 227–65.

but in a lesser degree, and cocaine produces numbness, but the difference in the sensation produced by the three alkaloids can with practice readily be distinguished. In the Lamson case, Dr. (afterwards Sir) T. Stevenson was questioned respecting the difference between aconitine, veratrine and delphinine when tested on the tongue.[1] The toxicity test on a frog or small animal also should be made.

Aconitine forms characteristic crystalline precipitates, even in dilute solutions, with both sodium carbonate and potassium permanganate,[2] which may be recognised microscopically, the former being a very sensitive test.

COCAINE.[3] The best test is that suggested by Hankin,[4] which is as follows :

Spread a drop of strong potassium permanganate solution on a microscope slide and allow it to dry. On the same slide near the permanganate film place a drop of saturated alum solution. Put into the alum solution a drop of the solution or a portion of the residue to be tested. With a cover slip draw the drop of alum solution up to the edge of the permanganate film and then allow the cover slip to fall so that the alum runs over the permanganate. If cocaine is present, characteristic crystals of permanganate of cocaine form. Novocaine does not form crystals with permanganate. Antipyrine interferes with the test and, if present, must be removed as follows : Add water, which dissolves the antipyrine and also a little of the cocaine, then add ammonia, which precipitates the dissolved cocaine ; filter and test the residue on the filter paper. Tropacocaine, alypin and scopalamine give somewhat similar crystals, which, however, with experience may be distinguished from one another and from the permanganate of cocaine.

2. Add a few drops of a 5 per cent. solution of chromic acid or of a 7·5 per cent. solution of potassium dichromate. If cocaine is present each drop of the reagent will produce a precipitate that disappears on shaking. Then add 1 c.c. of strong hydrochloric acid, which in the presence of cocaine will produce an orange-yellow precipitate.

3. Cocaine gives a characteristic crystalline precipitate with gold chloride, the test being carried out under the microscope.[5]

[1] H. L. Adam, *Trial of G. H. Lamson*, 1913, pp. 95–6.
[2] C. H. Stephenson, *Some Micro-Chemical Tests for Alkaloids*, 1921, p. 16.
[3] General References : (*a*) E. H. Hankin, " Tests for Cocaine and Certain other Anæsthetics," *Analyst*, **36** (1911), pp. 2–6 ; (*b*) P. A. Ellis Richards, " The Detection and Estimation of Cocaine, Heroine and Veronal in Viscera," *Analyst*, **44** (1919), pp. 192–6 ; (*c*) S. P. Sadtler, " Cocaine," *Allen's Commercial Organic Analysis*, **7** (1929), pp. 509–49 ; (*d*) M. D. Schwaikowa, *Medico-Legal and Criminological Review*, **3** (1935), p. 332 ; (*e*) F. Bamford, *Analyst*, **63** (1938), p. 648.
[4] E. H. Hankin, *op. cit.*
[5] See also A. Brüning, *Z. Unters. Lebensm*, 1940, **79** pp. 93–99. and *Analyst*, **65** (1940), pp. 427–428.

Cocaine has a bitter taste and produces numbness when applied to the tongue. The toxicity test on a frog or small animal also should be made.

HYOSCYAMINE.[1] The use of hyoscyamine as a poison is of frequent occurrence in Egypt, which arises from the fact that both *Hyoscyamus* and *Datura*, each of which contains hyoscyamine, grow wild. Of the latter there are several species, but only one variety of *Hyoscyamus*, namely *H. muticus*, is common. The seeds of *H. niger*, however, also are obtainable in Egypt being imported from India. Many of the cases of poisoning by hyoscyamine originate in drugging for the purposes of robbery, which is carried out in Egypt much in the same manner as in India, the seeds of either *Hyoscyamus* or *Datura*, generally whole though sometimes crushed, being mixed with something that the victim is persuaded to eat and in which they are not very noticeable, such as rissoles or figs or the paste made from crushed dates, all of which form effective disguises for the poison.

Hyoscyamine is closely allied chemically to atropine and hyoscine (scopolamine) and is present together with these in *Atropa belladonna*, and therefore all three alkaloids will be dealt with together. The best procedure is as follows [2]:

1. To show that the substance is a mydriatic alkaloid. This may be done by applying one or two drops of a 1 : 10,000 solution to the eye of a cat and observing the dilation of the pupil.

2. To prove that the substance is a vegetable mydriatic alkaloid. This may be shown by (*a*) the strong alkaline reaction with phenolphthalein and (*b*) Vitali's test, which consists in adding a few drops of strong nitric acid, evaporating to dryness on the water bath, and adding an alcoholic solution of potassium hydroxide when a bluish-violet colour is produced.[3]

Morin [4] dissolves the residue after nitric acid in 10 c.c. of anhydrous acetone and adds a 10 per cent. solution of potassium hydroxide in methyl alcohol drop by drop. He states that atropine and hyoscyamine give violet-colours more intense and more stable than those obtained by the usual method.

3. To identify the alkaloid. If sufficient material is available, this may be done by preparing the gold chloride or the picrate and observing the

[1] General Reference: F. H. Carr, "The Tropine Alkaloids," *Allen's Commercial Organic Analysis*, 7 (1929), pp. 803–40.

[2] F. H. Carr, *The Chemical World*, 1912, pp. 3–5.

[3] In the Crippen trial (Filson Young, *The Trial of H. H. Crippen*, pp. 73–4), Dr (Sir) W. H. Willcox stated in evidence that in the course of his investigations, which had included several hundreds of tests, some with viscera several years old, he had "never found . . . an animal alkaloid, which gave purple colour with the Vitali test."

[4] A. C. Morin, *J. Pharm. Chim.*, **128** (1936), pp. 545–547, and *Analyst*, **61** (1936), pp. 504 505.

crystalline forms and melting points of these salts. These latter are shown in the following table :

	Hyoscyamine. C.	Hyoscine. C.	Atropine. C.
Aurichlorides :			
Autenreith [1]	160°–162°	210°–214°	135°–137°
Carr [2]	165°	204°–205°	137°–139°
Henry [3]	165°	208°–209°	137°–139°
King [4]	—	204°–205°	—
Bamford [5]	—	208°	—
Picrates :			
Carr [2]	165°	187°–188°	175°–176°
Henry [3]	165°	187°–188°	175°–176°
King [4]	—	187°–188°	—
Bamford [5]	—	193°	—

In toxicological work there is considerable danger that during the process of extraction of hyoscyamine this alkaloid may be converted into its racemic modification atropine or hydrolysed into tropine or tropic acid ; also that hyoscine may be transformed into its optical isomeride *i*-scopolamine.

Wormley's Test for Hyoscine. A drop of hydrochloric acid saturated with bromine added to a solution of the alkaloid in dilute sulphuric acid (1 in 50) forms a yellow amorphous precipitate, which crystallizes on standing, distinct crystals being visible under the microscope unless the dilution is less than 1 per cent. in which case only reddish-yellow globules result. This test was relied upon by Willcox in the Crippen trial.

MORPHINE AND ITS DERIVATIVES.[6] The most commonly used derivatives of morphine are dionine (ethyl-morphine hydrochloride), heroin (diacetyl-morphine, frequently employed in the form of the hydrochloride) and dionyl (dipropionyl-morphine hydrochloride). Hankin and Chatterji [7] state that the only tests of any use for opium in viscera are (*a*) the porphyroxine test, (*b*) the Husemann reaction, and (*c*) the urotropin or formaldehyde reaction. The porphyroxine test was at one time thought to be applicable only to Indian opium,[8] but Bamford has shown [9] that specimens of both

[1] W. Autenreith, *The Detection of Poisons*, Trans. W. H. Warren, 1928, p. 185.
[2] F. H. Carr, " The Tropine Alkaloids," *Allen's Commercial Organic Analysis*, 7 (1929), p. 820.
[3] T. A. Henry, *The Plant Alkaloids*, 1924.
[4] H. King, *Journ. Chem. Soc. Trans.*, 1919, pp. 478-9.
[5] F. Bamford, *Poisons* : *Their Isolation and Identification*, p. 179.
[6] General References : (*a*) J. Webster, " Detection of Morphine in Acute and Chronic Cases," *Analyst*, **42** (1917), pp. 226–8 ; (*b*) J. R. Nicholls, " The Estimation of Morphine," *Analyst*, 1922 ; (*c*) F. O. Taylor, " Opium, Alkaloids," *Allen's Commercial Organic Analysis*, 7 (1929), pp. 655–758 ; J. R. Nicholls, " Mannich's Method for the Determination of Morphine," *Analyst*, **62** (1937), pp. 440–443.
[7] E. H. Hankin and D. Chatterji, " Note on Opium Poisoning," *Analyst*, **45** (1920), pp. 171–2.
[8] *Allen's Commercial Organic Analysis*, 6 (1912), pp. 403, 410.
[9] F. Bamford, (*a*) " Porphyroxine Test for Indian Opium," *Analyst*, **55** (1930), pp. 445–6 ; (*b*) *Poisons* : *Their Isolation and Identification*, p. 172.

Turkish and Smyrna opium give a positive reaction and he has since stated that " There is no known chemical test which enables one to differentiate them " . . . " I have applied this test to opium of known origin (Persian, Turkish and Indian) and obtained identical results in all three."[1] The test consists in warming the material to be tested with dilute hydrochloric acid when a red colour is developed if opium is present. The other two tests are as follows :

Husemann's Test. Dissolve a little of the suspected morphine residue in a drop of strong sulphuric acid, heat to 100°–105° C. for five minutes. Cool and add a drop of strong nitric acid. If morphine is present, a dark violet coloration is produced which gradually changes to blood-red and finally to orange. An alternative and better method is to allow the suspected residue, moistened with a drop of sulphuric acid, to stand in the desiccator for twenty-four hours before applying the nitric acid.

Formaldehyde Reaction (*Marquis Test*). To a minute portion of the suspected residue on a small watch glass a drop of a mixture consisting of 3 c.c. of strong sulphuric acid and two drops of formalin (40 per cent. formaldehyde solution) is added. A purple-red coloration changing to violet and finally to blue indicates morphine.

Other tests for morphine are as follows :—

(1) *Denigès* (*Denigès-Oliver*) *Test.* Dissolve a small portion of the residue in a few drops of dilute sulphuric acid : add one or two drops of hydrogen peroxide solution followed by sufficient ammonia solution to render alkaline and then one drop of copper sulphate solution (4 per cent.) and shake or otherwise mix. If morphine, or a morphine derivative, other than an ether of morphine, is present, a red colour is formed. Oliver stirs with a clean copper wire instead of adding copper sulphate and adds a few drops of potassium cyanide solution at the end of the reaction to remove any blue colour due to the copper.[2]

(2) A drop of modified Fröhde's reagent (0·1 gram ammonium molybdate dissolved in 10 c.c. of strong sulphuric acid), which must be freshly prepared, gives with morphine a red-violet colour changing to light green.

(3) Strong nitric acid gives an orange-red colour changing to yellow.

(4) *Pellagri's Test.* Dissolve a small portion of the solid residue in two drops of strong hydrochloric acid to which a small drop of strong sulphuric acid has been added. Heat on the water bath for half an hour. Cool, dilute with water, and add 2 drops of dilute

[1] F. Bamford, *Egyptian Government, Central Narcotics Intelligence Bureau, Annual Report for the Year* 1937, Cairo, 1938, p. 77.

[2] F. Bamford, " The Denigès-Oliver Test for Morphine," *Analyst*, 56 (1931), pp. 586–9.

hydrochloric acid. If morphine is present, the colour changes to red. Add a little sodium bicarbonate in fine powder until effervescence ceases and then a small drop of an alcoholic solution of iodine, when an emerald-green colour slowly develops. Excess of iodine spoils the test. If a little ether is poured on the surface of the liquid, the ether takes a purple tinge, the water solution remaining green.

(5) Dissolve a little of the residue in dilute sulphuric acid (1 in 50). Add a drop of 6 per cent. iodic acid in water or 8 per cent. potassium iodate solution (free from iodide) in 2 per cent. sulphuric acid. A faint yellow colour due to liberated iodine is produced if morphine is present. A drop of the mixture placed on a little powdered starch gives a blue colour, and the colour of the remaining liquid when treated with a drop of very dilute ammonia deepens to brown. This test is not specific and merely indicates the presence of a reducing substance. A control test should be made to guard against error due to the reagents containing free iodine. The esters of morphine (examples : heroin and dionyl) respond to this test more slowly than morphine.

(6) Morphine gives a characteristic crystalline precipitate with Marmé's reagent and heroin with mercuric chloride.

With reference to the Marquis test and the Denigès-Oliver test, Bamford states [1] : " As a result of wide experience in testing derivatives of opium I believe these two tests to be in practice a sufficient indication of the presence of alkaloids of the morphine group (except ethers of morphine, (examples : codeine and dionine) which do not give the Denigès-Oliver reaction) provided the presence of an alkaloid has been proved."

In the Chantrelle trial [2] the analyst for the defence stated that the tests for opium relied upon by the prosecution were not specific. These tests were (*a*) smell, (*b*) taste, (*c*) reaction for meconic acid with ferric chloride, and (*d*) reactions for morphine with sulpho-molybdic acid and iodic acid respectively.

In this connexion, dicodide, eucodal and dilaudide (which may be prepared from morphine, codeine or thebaine) should not be neglected, since many of the tests for these compounds closely resemble those for morphine and its more common derivatives. For the separation and identification of the three substances mentioned, the paper by King [3] should be consulted.

[1] F. Bamford, " The Fate of Apomorphine after Sub-cutaneous Injection," *Analyst*, **55** (1930), pp. 502–3.

[2] A. D. Smith, *Trial of E. M. Chantrelle*, 1906, pp. 129–32.

[3] J. King, " The Identification of Dicodide, Eucodal and Dilaudide," *Analyst*, **56** (1931), pp. 498–503.

STRYCHNINE.[1] The best test for strychnine is that with strong sulphuric acid and an oxidizing agent such as potassium dichromate or manganese dioxide. To carry out the test a portion of the suspected material is moistened with about two drops of strong sulphuric acid and a minute particle of potassium dichromate or better a little manganese dioxide is stirred in. In the presence of strychnine a purple-blue colour changing to purple, crimson and then to orange-red is produced.

2. Potassium ferrocyanide in hydrochloric acid solution affords a sensitive test for strychnine,[2] with which it gives long slender needles or spear-shaped crystals with serrated edges exhibiting oblique extension.

The presence of strychnine should be confirmed by the physiological tests, namely the taste and the result of injection into the dorsal lymph sac of a frog. Strychnine is extremely bitter, and when injected into a frog produces convulsions.

Yohimbine [3] (which physiologically bears a certain resemblance to cocaine and is sometimes used by drug addicts instead of cocaine) and the gelsemium alkaloids [4 5] may be mistaken for strychnine if the test with potassium dichromate or manganese dioxide alone is relied upon, since these substances give somewhat similar, though not identical, colour reactions as strychnine. The results obtained, however, may be interpreted correctly if parallel tests are made with known specimens of strychnine, yohimbine and gelsemin. Yohimbine may be identified by the characteristic crystalline compound it forms with potassium cyanide (5 per cent.).[6]

Colles [7] gives the following method of distinguishing gelsemin from strychnine. Make a solution of 0·02 gram of powdered potassium permanganate in 10 c.c. of water and pour into this slowly 16 c.c. of strong sulphuric acid, cooling under the tap. Drop a particle of the material to be tested into a drop of the mixture, when a blue colour will develop immediately which turns a permanent cherry-red if strychnine is present, whereas gelsemin, treated similarly, turns cherry-red immediately, but fades to a colourless liquid on standing.

[1] General Reference : C. A. Mitchell, " Strychnine Alkaloids," *Allen's Commercial Organic Analysis*, 7 (1929), pp. 759–802.

[2] H. I. Cole, " Potassium Ferrocyanide as a Reagent in the Microscopic Qualitative Chemical Analysis of the Common Alkaloids," *Phillippine Journ. of Science*, 23 (1923), pp. 97–101.

[3] W. Autenreith, *Laboratory Manual for the Detection of Poisons and Powerful Drugs*, trans. W. H. Warren, 1928, p. 387.

[4] R. A. Witthaus, *Manual of Toxicology*, 1911, pp. 941 and 1060.

[5] F. Peterson, W. S. Haines, and R. W. Webster, *op. cit.*, 2, pp. 510–11.

[6] C. H. Stephenson and C. E. Parker, *Some Micro-chemical Tests for Alkaloids*, p. 83. See also Perez, " New Specific Reaction for Yohimbine," *J. Pharm. Chim.*, 1935, 22, pp. 164–65 ; *Analyst* 60 (1935), p. 709.

[7] W. M. Colles, in *The Practice of Medicine in the Tropics*, W. Byam and R. G. Archibald, 1 (1921), p. 854

Poisonous Synthetic Drugs

The most important of these compounds are acetanilide, antipyrine, phenacetine, sulphonal and veronal. The tests may now be described. In the determination of the melting points, if the amount of material available is sufficiently large, the result obtained should be confirmed by the method of " mixed melting points," which consists in adding to the substance under test an equal weight of the pure material it is suspected to be and again taking the melting point, which should not show any change if the nature of the material has been correctly diagnosed.

Acetanilide (Antifebrine).

(1) Melting point 113° C. to 114° C.

(2) The distinguishing test for acetanilide is the formation of the characteristic and disagreeable odour of phenylisonitrile when heated with a few drops of alcoholic potassium hydroxide solution and a drop of chloroform. Heated with aqueous potassium hydroxide alone, the odour of aniline is given off.

(3) Acetanilide gives characteristic crystals with hydriodic acid and with bromine-potassium bromide.[1]

(4) The following confirmatory tests also should be applied. Boil a portion of the residue suspected to contain acetanilide with a few drops of strong hydrochloric acid for one minute, cool, dilute with ten to twenty drops of water and divide into four parts and test as follows :

(*a*) Indophenal reaction : To one portion add carefully one to three drops of a solution of fresh chlorinated lime (1 : 200) in such a manner that the solutions do not mix. A beautiful blue colour at the junction of the two liquids indicates acetanilide.[2]

(*b*) Mix a second portion with a small drop of 3 per cent. chromic acid solution. Acetanilide gives a yellow-green solution, changing to dark green on standing five minutes, with the formation of a dark bluish-green precipitate on addition of a drop of potassium hydroxide solution.[2]

(*c*) To a third portion add a small drop of a solution of potassium permanganate. A clear green colour is formed in the presence of acetanilide.[2]

(*d*) To the fourth portion add a few drops of 5 per cent. potassium nitrite solution, cool and make alkaline with sodium

[1] O. Tunmann, " Identification of the Poisons Extractable from Acid Aqueous Solution by Means of Ether according to the Stas-Otto Process," *Journ. Chem. Soc.*, **112** (1917), Abst. II, pp. 551–2.

[2] A. L. Winton and E. M. Bailey, " The Determination of Vanillin, Coumarin and Acetanilide in Vanilla Extract," *Journ. Amer. Chem. Soc.*, 1905, p. 721.

hydroxide and add a drop of an alcoholic solution of beta-naphthol. If acetanilide is present, a red azo dye is produced.

ANTIPYRINE [1] (PHENAZONE).

(1) Melting point 113° C.

(2) Steensma's reagent affords an excellent test. This reagent is prepared by dissolving one gram of paradimethylaminobenzaldehyde in 100 c.c. of a solution of 5 c.c. of 25 per cent. hydrochloric acid in 100 c.c. of absolute alcohol. When a liquid containing a trace of antipyrine is evaporated to dryness with 5 c.c. of this reagent, a beautiful fairly permanent rose-red colour is developed.

(3) Ferric chloride gives a blood-red coloration with antipyrine which is destroyed by mineral acids. The solution, however, is not decolorized, but still retains the colour due to the ferric chloride.

(4) A few drops of a solution of potassium or sodium nitrite followed by a drop of dilute sulphuric acid produces a green colour if antipyrine is present.

PHENACETINE.[2]

(1) Melting point 135° C.

(2) Add a few drops of strong hydrochloric acid and boil for half a minute, dilute with 10 c.c. of distilled water, cool, filter and add several drops of chromic acid solution; if phenacetine is present, a deep red colour is produced.

(3) Heat the suspected material to boiling with a few c.c. of 10 per cent. nitric acid. If phenacetine is present, a yellow to orange coloured solution is formed. If the solution is sufficiently concentrated nitro-phenacetine will crystallize out on cooling in the form of long yellow needles which melt at 103° C. Acetanilide and antipyrine give colourless solutions when warmed with dilute nitric acid.

(4) Phenacetine gives the indophenol reaction as described under acetanilide.

(5) When phenacetine is heated with alcoholic potash and chloroform it does not give the smell of phenyl-isonitrile which serves to distinguish it from acetanilide.

SULPHONAL.

(1) Melting point 126°–127° C.

(2) When sulphonal is heated with a little potassium cyanide in a dry

[1] General Reference: G. D. Lander, "Antipyrin in Toxicological Analysis," *Analyst*, **38** (1913), pp. 97–8.

[2] General Reference: O. Tunmann, "Identification of the Poisons Extractable from Acid Aqueous Solution by Means of Ether according to the Stas-Otto Process," *Journ. Chem. Soc.*, **112** (1917), Abst. II, pp. 551–2.

tube, mercaptan is formed which is recognized by its disagreeable smell. If the residue is dissolved in water and acidified with hydrochloric acid, the solution yields a reddish colour with ferric chloride.

(3) That the material is a sulphone may be proved as follows: Fused with sodium peroxide an orange-red mass results. A solution of a portion of this mass in water gives a purple colour with sodium nitroprusside: sulphur separates when the mass is treated with hydrochloric acid and the addition of barium chlorides gives a precipitate of barium sulphate. That the particular sulphone present is sulphonal and not trional or tetronal may be proved by a determination of the melting point.

VERONAL[1] (DIETHYL BARBITURIC ACID).

(1) Melting point 191° C.

(2) If to a little potassium hydroxide fused in a nickel crucible veronal be added while the hydroxide is molten, ammonia gas is evolved and the residue, when dissolved in water, gives, after acidifying with dilute hydrochloric acid, Prussian blue with a solution of ferrous sulphate and carbon dioxide and a fatty odour when acidified with dilute sulphuric acid. This test to be successful requires at least about 0·5 gram of material.

(3) Add two drops of nitric acid and test with Millon's reagent. A white gelatinous precipitate largely soluble in excess of the reagent is formed if veronal is present.

(4) Boil with a drop of 25 per cent. hydrochloric acid, make alkaline with sodium hydroxide and test with Nessler's solution. If veronal is present, a red precipitate is formed from the ammonium salt produced.

(5) Veronal gives characteristic crystals with zinc-chlor-iodide solution, hydriodic acid, bromine-potassium bromide and ammoniacal copper solution.[2]

Sometimes the presumptive evidence that death is due to a specific poison is so strong that the analyst is justified in making a special search for the poison in question. Thus if veronal is indicated the following method due to Willcox may be used.[3]

[1] General References: (*a*) P. A. Ellis Richards, "The Detection and Estimation of Cocaine, Heroine and Veronal in Viscera," *Analyst*, **44** (1919), pp. 192–6; (*b*) W. H. Willcox, "Veronal Poisoning," *Lancet*, **2**, 1913, pp. 1178–81.

[2] O. Tunmann, "Identification of the Poisons Extractable from Acid Aqueous Solution by Means of Ether according to the Stas-Otto Process," *Journ. Chem. Soc.*, **112** (1917), Abst. II, pp. 551–2.

[3] W. H. Willcox, "Veronal Poisoning," *The Lancet*, **2**, 1913, pp. 1178–81. See also L. Van Itallie and A. J. Steinhauer, "Extraction of Veronal," *Analyst*, **46** (1921), p. 413, and W. Autenreith, *Detection of Poisons*, 1928, pp. 567–9.

Viscera. Take a given weight (about 120 grams): mince finely and extract for 24 hours at 35° C. with 95 per cent. alcohol slightly acidified with acetic acid. Make four separate and successive extractions, decanting the liquid each time. Mix the extracts, filter and evaporate the filtrate to a syrup. Add about 200 c.c. of absolute alcohol and allow to stand. Filter and again evaporate to a syrup. Take up with water, filter and concentrate to about 15 c.c. by evaporation at a temperature not exceeding 35° C. Extract four times with ether or with ethyl acetate. Filter, mix the filtrates and evaporate to dryness. Weigh and test as described.

If the water extract is highly coloured, treat with lead acetate, filter, remove the lead in the filtrate with sulphuretted hydrogen, filter, concentrate and extract as above.

Urine. As veronal is excreted rapidly by the kidneys, the urine should be specially examined. Take about 200 c.c. of urine, add lead acetate, filter, remove the lead from the filtrate by means of sulphuretted hydrogen, filter, evaporate the filtrate to about 60 c.c., add a little animal charcoal, allow to stand for a few hours and filter. Concentrate the filtrate by evaporation at a low temperature to about 30 c.c.: extract three times with ether or with ethyl acetate. Filter, mix the filtrates and evaporate to dryness, weigh and test.

Other compounds of barbituric acid used medicinally in addition to veronal about seventeen of which are on the market, include allonal, dial, luminal, medinal, phanodorm, poponal, rutonal, soneryl and veramon. All the barbituric acid compounds are hypnotics. They behave differently in the body, some being destroyed completely or almost completely, while others may be found in considerable amount in the excreta and organs. Denigès gives a method for the microscopic crystalline identification of some of these compounds [1]; Ekkert deals with the differentiation of veronal, luminal and proponal [2]; Peltzer gives a method for the toxicological detection of veronal, luminal and phanodorm [3]; Koenig and Kluge describe the detection of luminal in urine [4]; Chéramy and Lobo describe the extraction of barbituric acid derivatives from viscera by means of acetone [5] and also a rapid method for the identification of barbiturates in blood [6]; Fauchet describes the

[1] G. Denigès, "The Micro-crystalline Identification of Barbituric Alkaloids," *Mikrochem.*, **9** (1931), pp. 316–23 (*Analyst*, **56** (1931), pp. 689–90).

[2] L. Ekkert, "Differentiation of Veronal, Proponal and Luminal," *Pharm. Zentralhalle*, 67 (1926), pp. 481–2 (*Chemical Abstracts*, 1926, p. 3330).

[3] J. Peltzer, "Toxicological Detection of Veronal, Luminal and Phanodorm," *Chem. Ztg.*, 57 (1933), p. 816 (*Analyst*, 58 (1933), pp. 773–4).

[4] W. Koenig and H. Kluge, "Detection of Luminal in Urine," *Chem. Ztg.*, **54** (1930), p. 541 (*Analyst*, 55 (1930), pp. 524–5).

[5] P. Chéramy and R. Lobo, "Extraction of Barbituric Acid Derivatives from Viscera by means of Acetone," *J. Pharm. Chim.*, **20** (1934), pp. 400–3 (*Analyst*, **60** (1935), pp. 50–1).

[6] P. Chéramy and R. Lobo, "Rapid Method for the Identification of Barbiturates in Blood," *op. cit.*, pp. 461–2 (*Analyst*, **60** (1935), p. 52).

identification of barbiturates in urine [1]; Roche Lynch discusses the toxicology of the barbiturates and thiobarbiturates, their extraction from urine and their identification,[2] and Chatfield gives a method for the identification of barbiturates and other barbituric acid derivatives.[3]

Metallic Poisons

The only metallic poisons that will be dealt with are arsenic, antimony, mercury, copper and lead, the last two, however, being of very slight forensic importance.

Arsenic. This is one of the commonest forms of poison used. In England oxide of arsenic (white arsenic) or arsenical weed killer is generally employed, but in the East (India and Egypt, for example) not only the oxide but the yellow sulphide (orpiment) and occasionally the red sulphide (realgar) are employed. Although the natural sulphides of arsenic are insoluble and, therefore, non-poisonous, the artificial sulphides are very poisonous, owing to the fact that as a result of their method of manufacture from oxide of arsenic (white arsenic) and sulphur they contain varying but generally large proportions of the very poisonous oxide.

The most important factor conditioning the nature of the particular substance used for poisoning purposes is probably the ease with which the substance in question may be obtained. Thus the extensive use of sulphide of arsenic as poison in Egypt is due to the fact that it can be obtained easily and can be bought clandestinely almost anywhere in the country despite the restrictions imposed on its sale by the Pharmacy Law, which results from its extensive employment for making the depilatory powder used for removing hair from certain parts of the body, a custom which Mohammedans consider essential to personal cleanliness. The powder consists of a mixture of sulphide of arsenic and slaked lime, which is made into a paste with water immediately before use and is applied in that condition. It is a frequent mistake in connexion with these powders to regard the arsenic as the important and essential ingredient, whereas it is the sulphide, which forms calcium sulphide with the lime, that is valuable, and sulphides other than those of arsenic are equally effective, for example sodium sulphide and barium sulphide, and depilatory powders containing the latter are now made.

During the trial of Mrs. Maybrick, one of the witnesses (a hairdresser), who was evidently under the common and erroneous impression that arsenic is the active agent, stated [4] that in the course of his business he made

[1] M. Fauchet, "Identification of Barbiturates in Urine," *J. Pharm. Chim.*, **20** (1934), pp. 403–6 (*Analyst*, **60** (1935), p. 51).

[2] G. Roche Lynch, "The Toxicology of the Narcotic Drugs, *Analyst*, **63** (1938), pp. 240–250.

[3] R. F. Chatfield, *Pharm. J.*, 1939, pp. 143, 346; *Analyst*, **64** (1939), pp. 893–894. See also F. Bamford, *Poisons: Their Isolation and Identification*, pp. 286–290.

[4] H. B. Irving, *Trial of Mrs Maybrick*, 1912, pp. 224–5.

depilatory powders, using arsenic and lime, and that generally he employed yellow arsenic, though sometimes white arsenic. White aresnic, however, is useless for this purpose, and any depilatory effect produced by a mixture of white arsenic and lime is due entirely to the lime.

The best methods of testing for arsenic in cases of poisoning or suspected poisoning, where the amount of poison present is small, are the Reinsch test and the Marsh test, the former being used as a preliminary qualitative test and the latter either as a qualitative test or for a quantitative determination.

The Reinsch Test. This test, which is one of the simplest and most valuable, depends upon the fact that metallic copper in boiling dilute hydrochloric acid acts upon soluble compounds or arsenic, antimony, mercury, bismuth and a few other substances, forming in the cases of arsenic and antimony double compounds of arsenic and copper and antimony and copper respectively, which are deposited as a thin film on the copper, though probably small amounts of the elements arsenic and antimony are also present.[1] [2]

The test is very sensitive, and will detect readily as little as half a milligram of arsenic in 50 c.c. of liquid. Another good feature of the test is that it can be applied without the destruction of organic matter. Urine should be evaporated on the water bath to about one-fourth of its volume, vomit is mixed with water, and solid matter is minced finely and sufficient water added to make the mixture the consistency of thin gruel. If the liquid is acid, it should be made slightly alkaline by the addition of sodium bicarbonate. One important precaution to be observed is to ensure the absence of any oxidizing agent. Another is that the hydrochloric acid employed must be absolutely free from arsenic. If arsenic-free acid is not available, it can be made in the manner to be described later. The copper also should be free from arsenic, and such copper is readily obtainable. In one case on record,[3] the presence of arsenic in the copper and chlorate in the solution led to a serious mistake being made, owing to a little of the copper dissolving and the arsenic it contained being deposited.

The Reinsch test should always be begun by a control experiment to test the purity of the materials used. For this purpose 50 c.c. of pure hydrochloric acid of not more than 8 per cent. strength are placed in a conical flask and a thin strip of clean, bright copper foil about half an inch (12 mm.) by a quarter of an inch (6 mm.) in size is inserted and the solution kept simmering gently for about 15 minutes. If at the end of this time the

[1] B. S. Evans, "An Investigation into the Chemistry of the Reinsch Test for Arsenic and Antimony," *Analyst*, **48** (1923), pp. 357–67, 417–29.

[2] S. Torrance, "The Electrical Deposition and Determination of Arsenic," *Analyst*, **63** (1938), pp. 104–107; *Analyst*, **64** (1939), pp. 263–4.

[3] A. Wills, *Circumstantial Evidence*, 1912, p. 368.

copper is still bright, the materials are pure and the test can be proceeded with, but if any signs of a grey deposit appear on the copper, the materials are not sufficiently pure and should not be used.

The copper foil may be suspended in the liquid by means of fine platinum wire or held in a clip made by bending the end of a glass rod twice round parallel to itself,[1] or in a glass fork, the ends of which are bent upwards to form a hook,[2] or it may simply be placed in the liquid and its condition examined from time to time through the bottom of the flask.

It is essential that the copper used should be bright and clean, and in order to clean it fuming nitric acid is used, or the following mixture recommended by Hankin, namely 100 parts water, 100 parts strong sulphuric acid, 50 parts strong nitric acid and 2 parts strong hydrochloric acid.[3] In either case the foil is dipped momentarily into the acid, well washed in running water and used immediately.

When the reagents have been proved to be free from arsenic, about 100 c.c. of the material to be tested is added to the flask, which is kept simmering, the evaporated liquid being replaced from time to time by adding a little hot distilled water. If much arsenic is present, a film is formed on the copper within a few minutes, but if at the end of half an hour the copper remains bright, the material is free from arsenic, unless sulphuretted hydrogen, generated by putrefaction, has converted all the arsenic into sulphide, which does not respond to the Reinsch test. Under certain conditions, too, arsenates are not reduced to arsenites and fail to respond. If a deposit is obtained on the copper, although this may be due to arsenic it is not necessarily a proof of its presence, since other substances, as already stated, notably antimony, mercury and bismuth, also may be deposited on the copper under the conditions of the test or the copper may become stained by organic matter or by sulphur compounds. Some indication of the possible nature of the film may be obtained from its colour, arsenic films varying from steel-grey to black, antimony films being generally purple, mercury films silvery to zinc-grey and bismuth and sulphur films black. The presence of arsenic therefore must be confirmed. This is done as follows: Remove the foil, rinse it with water, then with alcohol and ether, or simply with petroleum ether, dry it thoroughly either between filter paper or at a temperature not exceeding 100° C., cut it into strips and introduce them into a small (5 mm. diameter) dry tube, preferably a flat sublimation tube, and gently heat in a small flame, the upper portion of the tube being warmed before beginning the sublimation in order to obtain better crystals if arsenic is present, since arsenious oxide is liable to condense on a cold surface in the amorphous condition. Any sublimate obtained is

[1] F. N. Windsor, *Indian Toxicology*, 1906, p. 15.
[2] B. S. Evans, *Analyst*, 48 (1923), p. 360.
[3] L. A. Waddell, *Lyon's Medical Jurisprudence for India*, p. 485.

examined under the microscope. If the material tested contained arsenic, the sublimate will consist of arsenious oxide and is in the form of well marked octahedral crystals which are characteristic and absolute proof of the presence of arsenic. Unless satisfactory crystals are obtained, the presence of arsenic is not proved.

Sometimes on heating the copper in order to obtain sublimation, charring occurs and liquid is given off that obscures the sublimate. If this happens, another piece of copper having the deposit should be taken and placed in ether for twenty-four hours, after which it is dried with blotting paper and heated in the usual way (Hankin).[1]

With reference to the Reinsch test the Royal Commission on Arsenical Poisoning say [2]: "But we are now satisfied that the use of the Reinsch test entails considerable risk of missing quantities of arsenic which, though small, are not to be regarded as negligible."

The Marsh Test. This consists in introducing the material to be tested into an apparatus evolving nascent hydrogen which reduces any arsenic or antimony compounds present, combining with the metal to form arseniuretted hydrogen (arsine) or antimoniuretted hydrogen (stibine) as the case may be. The apparatus consists essentially of a small flask fitted with a stoppered funnel, a tube filled with calcium chloride to dry the evolved gases and an exit tube drawn out to a point at the end and having one or more constrictions in the middle. This tube is made of hard glass or transparent silica, and is strongly heated at the constricted sections, the arsine or stibine being decomposed and the metal deposited on the inner walls of the tube in the form of a dark coloured metallic-looking film termed a "mirror." It is stated that the sensitiveness of the test is much increased if the diameter of the tube is about 0·3 mm.[3]

In the Report of the Royal Commission on Arsenical Poisoning, three different forms of Marsh apparatus are described,[4] one, the ordinary form recommended by a Joint Committee of the Societies of Chemical Industry and Public Analysts,[5] the second, an electrolytic modification using platinum electrodes, recommended by the Inland Revenue Departmental Committee,[6] and the third, a modification of the usual method by McGowan and Finlow which has never come into general use, in which the greater part of the hydrogen is evolved in a separate apparatus. The detailed descriptions of

[1] L. A. Waddell, *Lyon's Medical Jurisprudence for India*, 1914, p. 485.
[2] *Final Report, Part I*, p. 20.
[3] O. Billiter and E. Marfurt, "Detection of Minute Quantities of Arsenic," *Journ. Soc. Chem. Ind.*, **42** (1923), p. 1155 A.
[4] Vol. II, 1903, pp. 206, 208 and 221.
[5] See also *Analyst*, **27** (1902), pp. 48–53 and *Journ. Soc. Chem. Ind.*, **21** (1902), pp. 94–6.
[6] See also *Journ. Chem. Soc.*, **83** (1903), *Trans.*, pp. 974–86, and *Analyst*, **28** (1903), pp. 349–59.

these different methods will not be transcribed, since the originals are readily available.

The electrolytic method is the most satisfactory as it eliminates all possibility of the employment of impure zinc.[1] When the platinum becomes dull, as it does with use, low results are obtained owing to the retention of arsenic. To avoid this, lead [2] and more recently lead amalgamated with mercury [3] have been proposed in place of platinum. Lead, although ordinarily satisfactory in practice, suffers from the disability that it would be difficult to prove, without destroying the apparatus, that it was not contaminated with arsenic.

In a modification of the Marsh test recently described by Evans,[4] the arseniuretted hydrogen is passed over ignited copper, the gain in weight of which is a measure of the amount of arsenic present.

When using the Marsh test for arsenic determination, the liquid tested must be free from organic matter and the arsenic preferably should be in the form of arsenite, the latter becoming essential when the electrolytic method is employed. The following precautions are essential, namely (*a*) that the reagents are free from arsenic, (*b*) that zinc when used must be " sensitive " and permit all the arsenic present to be evolved, and (*c*) that substances liable to retard or prevent the evolution of arsenic are absent. These possible sources of error will now be considered.

PURITY OF THE REAGENTS. This may be proved by making a blank experiment of an hour's duration after ensuring that conditions (*b*) and (*c*) are satisfactory.

Hydrochloric Acid. This may be freed from arsenic as under :

1. Take the " pure " acid as purchased for analysis : dilute with distilled water to a specific gravity of 1·1 and add sufficient bromine to colour it strongly yellow (about 5 c.c. per litre) ; sulphurous acid, either gaseous or in aqueous solution, is then added *in excess*, and the mixture is allowed to stand for at least twelve hours. Or hydrobromic acid and sulphurous acid may be used. The acid is boiled until about one-fifth has evaporated. The residue can be used direct, the arsenic having volatilized with the first portion.[5]

[1] This method is discussed by H. J. S. Sand and J. E. Hackford (*Journ. Chem. Soc.*, **85** (1904), *Trans.*, pp. 1018–28).

[2] T. Callan, " The Use of the Lead Cathode in the Electrolytic Method for the Determination of Minute Quantities of Arsenic," *Journ. Soc. Chem. Ind.*, **43** (1924), pp. 168 T–170 T.

[3] F. S. Aumonier, " A Simple Mercury Cathode for Arsenic Determinations," *Journ. Soc. Chem. Ind.*, **46** (1927), T 341–5.

[4] B. S. Evans, " A New Process for the Estimation of Arsenic with Notes on the Chemistry of the Marsh-Berzelius Process," *Analyst*, **45** (1920), pp. 8–17.

[5] Report of the Joint Committee of Societies of Chemical Industry and Public Analysts, *Royal Commission on Arsenical Poisoning*, **2**, p. 206. Also *Journ. Soc. Chem. Ind.*, **21** (1902), p. 94, and *Analyst*, **27** (1902), pp. 210–11.

2. Take the " pure " acid : dilute with distilled water to a specific gravity of 1·1 and distil with potassium dichromate.[1]

3. Take the " pure " acid : dilute with distilled water to a specific gravity of 1·1, boil in it a small copper-tin couple and distil.[2]

With none of these processes is the acid obtained always satisfactory, and invariably it should be tested before use.

Sulphuric Acid. To about half a litre of the acid sold as " pure for analysis " add a few grams of pure sodium chloride and distil from a non-tubulated glass retort, rejecting the first 50 c.c. of the distillate.[3]

The purified acids should not be stored for any length of time, since most bottle glass is liable to communicate traces of arsenic.

Calcium Chloride. This, which should be in the form of small granules and neutral in reaction, frequently contains arsenic and may be purified by moistening with hydrochloric acid, fusing and re-granulating.[3]

Dyer states [4] that much of the calcium chloride obtainable is strongly absorptive of arseniuretted hydrogen, especially if used for more than two experiments. The calcium chloride therefore should be renewed after each positive test and after every two negative tests.

Ward states [5] that cotton wool when employed for stopping the ends of the calcium chloride tube retains arsenic, probably in the form of hydride : he recommends instead the use of glass wool (well washed and dried).

Zinc. Zinc may be freed completely from arsenic by melting it with a small proportion of metallic sodium, removing and rejecting the scum that forms, repeating the operation and then granulating.[2]

Sensitiveness of the Zinc.[6] Pure zinc is often insensitive and does not permit the evolution of all the arsenic in the solution, and the sensitiveness of the zinc, therefore, must be regarded as an essential feature of the Marsh process. The best method to ensure that the zinc is sensitive is to coat it with metallic cadmium before use. Chapman, to whom this method is due, states [7] that success depends very largely upon the uniform character of the cadmium coating and recommends about 4 grams of cadmium sulphate to

[1] G. McGowan and R. S. Finlow, *Royal Commission on Arsenical Poisoning*, 2, p. 220.

[2] L. T. Thorne and E. H. Jeffers, " The Purification of Zinc and Hydrochloric Acid from Arsenic," *Analyst*, 31 (1906), pp. 101–5.

[3] Report of the Joint Committee of Societies of Chemical Industry and Public Analysts, *Royal Commission on Arsenical Poisoning*, 2, *p.* 206. Also *Journ. Soc. Chem. Ind.*, 21 (1902), p. 94 and *Analyst*, 27 (1902), pp. 210-11.

[4] B. Dyer, *Analyst*, 45 (1920), p. 17.

[5] T. J. Ward, " Effects of Cellulose on Arsenic Determinations," *Analyst*, 51 (1926), p. 457.

[6] A. C. Chapman and H. D. Law, " The Estimation of Traces of Arsenic by the Marsh-Berzelius Method and the ' Insensitiveness ' of Zinc," *Analyst*, 31 (1906), pp. 3–16.

[7] A. C. Chapman, " The Estimation of Minute Traces of Arsenic," *Analyst*, 32 (1907), pp. 247–9.

about 10 to 15 grams of zinc, the operation being carried out in the evolution flask of the Marsh apparatus. The details of the method are as follows:

Twenty-five grams of pure granulated zinc are treated quickly with dilute nitric acid and then washed thoroughly with water and finally put into a flask containing two grams of cadmium sulphate or chloride dissolved in 50 c.c. of water. This is allowed to stand on the water bath with occasional shaking until a grey spongy deposit of cadmium completely covers the zinc. The liquid is poured off and the zinc washed twice with water by decantation. The sensitiveness of the zinc is controlled by making a test and seeing that a distinct arsenic mirror is obtained with one-hundredth of a milligram of arsenious oxide. If insensitive, the cadmium coating is increased, after which, if still unsatisfactory, the zinc must be rejected.

Absence of Deleterious Substances. Among the substances that retard or entirely prevent the evolution of arseniuretted hydrogen are iron, platinum, copper, nickel and cobalt. The reagents therefore must be free from these substances. The presence of oxidizing agents such as potassium chlorate, chlorine, bromine, nitrates and nitric acid must also be avoided, as these would prevent the formation of arseniuretted hydrogen by inhibiting the reducing action of the hydrogen. Oxidizing agents may be removed (*a*) by the addition of a few drops of stannous chloride to the warm solution, or preferably and safer (*b*) by adding 0·5 gram of potassium metabisulphite or of sodium bisulphite and warming on the water bath for half an hour until no smell of sulphur dioxide remains.[1]

The Marsh test should be begun by a control experiment to test the purity of the reagents and the satisfactory working of the apparatus. This experiment is allowed to run for twenty minutes, after which the solution to be tested is introduced in portions of 10 c.c. at a time, 20 c.c. being added altogether. In from five to twenty minutes, a mirror should begin to form if arsenic is present. If there is no formation of a mirror, a further 15 c.c. of solution is added, together with 10 c.c. of acid. If no mirror is formed after half an hour, arsenic is absent. If the test is positive, the experiment should be allowed to continue for forty-five minutes.

Standard Mirrors. When a satisfactory blank experiment has been obtained, a series of standard mirrors representing known quantities of arsenic must be prepared in order that, by comparison with the standards, the amount of arsenic in the sample tested may be estimated. The standard mirrors are made as follows[2]: A hydrochloric acid solution of arsenious acid containing in each cubic centimetre 0·001 milligram of oxide is prepared by diluting a stronger solution with distilled water. Two c.c. of this solution

[1] W. A. Davis and J. G. Maltby, "The Risk of Error in Determining Traces of Arsenic in Organic and Inorganic Materials," *Analyst*, **61** (1936), pp. 96–100.

[2] Joint Committee's Report, *Royal Commission on Arsenical Poisoning*, **2** (1903), p. 206.

(equal to 0·002 mg. of arsenious oxide) are introduced into the apparatus and, after twenty minutes, the portion of the tube containing the mirror is sealed off while still filled with hydrogen ; in contact with air, the mirrors gradually fade. Mirrors are now made similarly with 0·004, 0·006, 0·008, 0·01 mg. and so on, of arsenious oxide. With quantities greater than 0·2 mg. the mirrors become too dense for accurate comparison. With a little practice, it is easy to obtain the deposits of arsenic neatly and equally distributed. The standard mirrors, properly marked, are mounted on a white card. If sulphuric acid is used for the testing and not hydrochloric acid, the standard mirrors must be made with sulphuric acid, as with small quantities of arsenic there is a difference in intensity between the mirrors made with the two acids. The Marsh test is so sensitive and detects such minute traces of arsenic that in viscera, vomit or urine in legal cases no mirror indicating an amount of arsenic less than one-fiftieth of a milligram should be considered positive, since less than this amount may be derived from sources other than poison administered criminally, such for instance as food,[1] glass bottles and chemicals and apparatus, even though these latter are specially purified. In the case of hair and finger nails, however, amounts of less than one-fiftieth of a milligram of arsenic may be significant.

With reference to the Marsh test the Royal Commission on Arsenical Poisoning make the following statements [2] :

" The evidence shows that it is now recognized that a satisfactory estimation of the arsenic in a given substance can be made by comparing mirrors obtained by the Marsh-Berzelius method, after the substance examined has been subjected to appropriate treatment by which any arsenic present is obtained in a solution suitable for the proper application of the test.

" This method has lately been investigated in much greater detail than formerly, and certain new and important points have been worked out. It is, for instance, now recognized as essential, not only to obtain zinc and acid which are free from traces of arsenic and to verify this freedom by control experiments, but also to see that the zinc used is ' sensitive,' and will permit all the arsenic in the solution to be evolved as arseniuretted hydrogen. Another matter brought out by recent investigation is that the presence in the solution of certain metals, notably iron, is liable to retard, or entirely to prevent, the evolution of arseniuretted hydrogen, and thus may seriously affect the estimation.

" We are satisfied that careful analysts who estimate arsenic by this method can obtain results sufficiently exact and comparable for practical purposes, although the details of their procedures may differ.

[1] See H. E. Cox, " On Certain New Methods for the Determination of Small Quantities of Arsenic and its Occurrence in Urine and in Fish," *Analyst*, 50 (1925), pp. 3–13.

[2] *Final Report, Part I*, pp. 16–18.

" General experience of this test has shown that when in the preparation of ' standard ' mirrors the quantities of arsenic added to the apparatus differ by amounts such as 0·002 milligram, a series of mirrors can be obtained showing differences in intensity which are sufficiently distinct and constant to be utilized for comparison. If the test is applied to a solution obtained from 10 grams of a given substance, a difference in mirrors corresponding to 0·002 milligram represents 2 parts of arsenic per million in the substance taken, or 0·0014 ($\frac{1}{700}$th) of a grain of arsenic per lb. If applied to 50 c.c. of a given liquid, a difference of 0·002 milligram in the mirror represents 0·04 parts of arsenic per million in the liquid, or 0·0028 ($\frac{1}{350}$th) of a grain of arsenic per gallon.

" Distinctions of greater or less delicacy can of course be made (within practicable limits) by increasing or diminishing the quantity of substance taken for the purposes of the test.

" As regards *detection* of arsenic by the Marsh-Berzelius method, the evidence shows that when various substances are taken in quantities which have been found practically convenient, the presence of arsenic will be detected when in amounts well below $\frac{1}{1000}$th grain per pound or (in the case of a liquid) well below $\frac{1}{300}$th grain per gallon." These figures represent 0·14 milligram per kilogram and 0·05 milligram per litre respectively.

The Commission also state that " a difference in reading corresponding to 0·002 milligram of arsenic too much or too little appears to be regarded as an outside limit " that is possible for errors due to differences in personal judgment and other factors.

The arsenic in the mirror may be determined quantitatively if desired by dissolving it in from 5 to 10 times the theoretical quantity of iodine solution (0·005 to 0·01 Normal) containing a little sodium bicarbonate and titrating the excess of iodine by a standard solution of sodium thiosulphate in presence of starch after acidifying with hydrochloric acid. Special burettes should be used having a capacity of 0·5 c.c. and graduated to 0·002 c.c.[1]

It may be mentioned here that the Royal Commission's Report on Arsenical Poisoning contains much valuable information with respect to (*a*) the possible presence of arsenic in various foods, (*b*) the examination of enamelled iron cooking vessels for arsenic, (*c*) the accumulation of arsenic in human tissues and the manner in which it is eliminated, and (*d*) the elimination of arsenic by the hair.

Destruction of Organic Matter. Before using the Marsh test organic matter present usually must be destroyed.[2] A discussion of the extent to

[1] O. Billiter and E. Marfurt, " Detection of Minute Quantities of Arsenic," *Journ. Soc. Chem. Ind.*, 42 (1923), p. 1155 A.

[2] If the residue after extraction for alkaloids by alcohol is employed, the alcohol must first be evaporated off on the water bath.

which this is necessary and various methods employed will be found in the Report of the Royal Commission.[1] The method applied generally to viscera is that known as the Fresenius-Babo method and is as follows:

Mince the material finely in a mincing machine, take 150 grams if available, or as much as possible up to this amount, place in a porcelain basin and add 70 c.c. hydrochloric acid (sp. gr. 1·1) mixed with three times its volume of water, or less in proportion if less material is used. Stir well, add a little pure potassium chlorate[2] and heat on a boiling water bath. Additional small quantities of potassium chlorate (about one-third of a gram at a time) are added at intervals of a few minutes, the volume of the liquid being kept constant by the addition of water from time to time. The solid matter gradually goes into solution and the liquid becomes yellow. The addition of chlorate is continued until the yellow colour ceases to change to brown, after which the liquid is heated further until it just begins to darken in colour, an indication that the chlorate has been decomposed. It is now allowed to become quite cold, when a considerable quantity of solid matter separates out. The clear portion is decanted off and filtered. The residue in the basin is washed two or three times by being warmed with water and a little hydrochloric acid. The solution is cooled each time, filtered and added to the main bulk. The cooling is important, otherwise more solid matter will be deposited later and further filtration will be necessary. The mixed filtrate and washings are returned to the basin and evaporated on a water bath to a volume of about 200 c.c., one or two further crystals of chlorate being added from time to time should the liquid tend to become dark coloured. The liquid is allowed to cool and 10 to 15 c.c. of a saturated aqueous solution of sulphurous acid are added in order to reduce the arsenic to the arsenious condition. It is allowed to stand for some time and the sulphurous acid then evaporated off, care being taken that the hydrochloric acid never becomes too concentrated, otherwise arsenic will be lost by evaporation as trichloride. It is afterwards cooled and if necessary filtered. From this the arsenic is precipitated by sulphuretted hydrogen (or the liquid is diluted to a given volume and an aliquot part taken). This is done by passing a slow current of sulphuretted hydrogen through for an hour and the flask (which should be nearly full) is tightly corked and allowed to stand in a warm place until the next day, when more sulphuretted hydrogen is passed in and the flask again corked. If after two days more the liquid still smells of sulphuretted hydrogen, it is filtered through asbestos in a Gooch crucible, the precipitate being washed with a little sulphuretted hydrogen water. It is important that the volume of this wash water should

[1] 2, pp. 223–224.

[2] Potassium chlorate must be added before the heating commences in order to oxidize any trivalent arsenic present to the pentavalent form, otherwise arsenic may be lost as volatile chloride.

not be more than about 20 c.c., otherwise the sulphide of arsenic is apt to assume the colloidal form and to pass through the filter.

Any sulphuretted hydrogen used must be free from arsenic and is prepared best by dropping strong hydrochloric acid from a tap funnel into a mixture of calcium sulphide or barium sulphide and water. The calcium sulphide may be made by heating to a bright-red heat a mixture of seven parts of pure plaster of paris, three parts of powdered wood charcoal and one part of flour or starch.[1] Crookes recommends [2] taking impure sulphuretted hydrogen as ordinarily generated and passing it into water containing magnesium oxide in suspension, when magnesium hydrosulphide is formed. The liquid is allowed to settle, decanted and placed in a generating flask, which is heated to 60°–65° C., when sulphuretted hydrogen is evolved. Autenreith recommends [3] an analogous method, impure sulphuretted hydrogen being passed to saturation into dilute (10 per cent.) sodium hydroxide solution, which is then put into a tap funnel and dropped slowly into cold dilute sulphuric acid (1 : 4), when sulphuretted hydrogen is given off.

In all cases the purity of the sulphuretted hydrogen should be tested before use by passing it into warm destruction fluid (8 per cent. hydrochloric acid and potassium chlorate), containing a few cubic centimetres of nitric acid or a little ferric chloride, working up the resulting precipitate, which is chiefly sulphur, and testing it for arsenic in the Marsh apparatus.[4]

The asbestos containing the washed precipitate is then transferred to a small porcelain basin, the crucible being rinsed out with a little water. After warming the basin on a water bath to disintegrate the asbestos, 2·5 c.c. of aqueous ammonia (1 in 5) are added and the warming continued for a short time and the liquid filtered through a small filter paper, and this extraction with small quantities of ammonia and water is continued until both the asbestos and the solution are colourless. The filtrate is evaporated on a water bath to dryness or until all the ammonia is expelled, 2 c.c. of concentrated nitric acid are added and the liquid is digested on the water bath with subsequent small additions of nitric acid if necessary (about 1 c.c. at a time) until it is pale yellow. The free nitric acid is evaporated off and the residue extracted with a few cubic centimetres of a warm aqueous solution of ammonium carbonate (1 in 4) in order to remove any sulphur present. The liquid is again filtered, evaporated on the water bath until free from ammonia, and the residue treated with nitric acid and evaporated to dryness. Then 8 to 10 drops of concentrated sulphuric acid are added

[1] W. M. Colles, in *The Practice of Medicine in the Tropics*, by W. Byam and R. G. Archibald, **1** (1921), p. 836.
[2] W. Crookes, *Select Methods of Chemical Analysis*, p. 487.
[3] W. Autenreith, *op. cit.*, p. 247, n. 2.
[4] W. M. Colles, *op. cit.*, pp. 828, 837.

and the basin heated until the contents are thoroughly charred. The sulphuric acid is driven off, a Bunsen flame being used, but this operation must be performed very cautiously and no part of the basin must ever approach a red heat. If the smell of sulphurous acid can be detected in the escaping fumes, the heating must be stopped and the contents of the basin again treated with nitric acid as before. When all the sulphuric acid has been driven off the charred residue is extracted several times with small quantities of water acidulated with sulphuric acid and filtered. To the filtrate, which must be clear, colourless and without smell, a few drops of an aqueous solution of sulphurous acid are added, and after the excess of this acid has been removed by evaporation, the liquid is ready for testing in the Marsh apparatus.[1]

Another method of destroying organic matter that is particularly suitable for small amounts of material is as follows [2]:

Ten grams of the substance are placed in a 3½-inch porcelain crucible and covered with pure re-distilled nitric acid (about 10 to 15 c.c.). The crucible is heated on a sand bath until the evolution of brown fumes ceases. Three cubic centimetres of concentrated arsenic-free sulphuric acid are then added and the heating continued till the mass just begins to char, when a further 5 c.c. of nitric acid are added. The heating is continued till all the acid is expelled, leaving in the crucible a black, nearly dry, charred mass. The crucible is then about half filled with water and a few c.c. of hydrochloric acid or of dilute sulphuric acid (according to which will be used in the Marsh test) are added and the residue allowed to extract on a water bath for about half an hour, after which it is filtered into a porcelain basin, the charred mass washed with hot water and the filtrate and washings evaporated to about 30 c.c., which is allowed to cool, and is then ready to be tested in the Marsh apparatus.

A much simpler method for destroying organic matter and one that is perfectly reliable except when mercury has to be tested for, is that of Stryzowski,[3] which, slightly modified by Bamford,[4] is as follows: Mince 100 grams of viscera; add 35 c.c. of saturated magnesium nitrate solution made alkaline to litmus with magnesium oxide; heat gently on a sand bath, care being taken to avoid too violent an action, which might result in loss; transfer to a silica basin and heat over the blowpipe or in a muffle furnace to a dull red heat until a grey or white ash is obtained [5]; allow to cool;

[1] A modification of the method given is described by G. Roche Lynch ("The Estimation of Arsenic," *Lancet*, 2, 1922, pp. 629–60).

[2] *Royal Commission on Arsenical Poisoning*, 2, pp. 207–24.

[3] J. W. Holland, "Inorganic Poisons," in *Legal Medicine and Toxicology*, edited by Peterson, Haines and Webster, 2, 1923.

[4] F. Bamford, *Poisons: Their Isolation and Identification*, p. 76.

[5] Any arsenic or antimony present is converted respectively into magnesium pyroarsenate or pyroantimonate, both of which are sufficiently stable to withstand moderate heating without loss.

take up in hydrochloric acid; filter and test for the metals in the usual manner or use direct in the Marsh apparatus after the addition of stannous chloride.

The Gutzeit Test. This is a useful qualitative test for arsenic when phosphorus and antimony have been proved to be absent. It is well described by Bamford.[1]

Ultra-Violet Ray Test. Under certain conditions arsenic compounds give a marked fluorescence when exposed to the ultra-violet rays, thus stains on the mercuric perchloride paper used in the Gutzeit test for arsenic, that are so faint as to be invisible, become visible when viewed under ultra-violet radiation.[2] In a recent important trial in Berlin a fluorescent test for arsenic was admitted as evidence.[3]

Spectrographic Test. Arsenic may be determined spectrographically, though as a rule this test is too delicate for use in poisoning cases.

Arsenic in large Amount. In cases where the amount of arsenic is sufficiently large to permit of its being determined by weighing, this is best done as follows: A weighed portion of the organ found to contain arsenic is taken, the organic matter destroyed by one of the methods described and the arsenic precipitated as arsenious sulphide by means of sulphuretted hydrogen,[4] the liquid being kept saturated with the gas for four days. The sulphide is filtered off, dried, freed from sulphur and weighed and its purity confirmed by converting it into pyroarsenate, which is weighed.[5] [6]

Antimony. The only soluble compound in common use or easily procurable is tartar emetic, and this, therefore, is the compound usually employed for poisoning purposes. Antimony may be detected both by the Reinsch test and the Marsh test. In the Reinsch test the film deposited on the copper is generally of a purple colour. The sublimate obtained by heating the copper, which consists of antimony trioxide and is largely amorphous in character, requires a higher temperature for its formation than that of arsenic. This sublimate however may contain crystals, some of which are octahedral or occasionally prismatic. Selenium, which also forms a stain upon copper, also produces a sublimate largely amorphous, but which may contain prismatic crystals arranged in feathery bundles. If

[1] F. Bamford, *Poisons: Their Isolation and Identification*, 1940. See also H. E. Crossley, "Modification to the Gutzeit Method for the Determination of Arsenic," *Journal, Society of Chemical Industry*, 55 (1936), pp. 272 T–276 T.

[2] A. A. King, "Ultra-Violet Radiation in Industry," *Journal Society of Chemical Industry*, 47 (1928), p. 304.

[3] L. V. Dodds, "Industrial Use of Ultra-Violet Light," *Discovery*, 9 (1928), pp. 178–80.

[4] See p. 296.

[5] G. Roche Lynch, "The Estimation of Arsenic," *Lancet*, 2 (1922), pp. 629–30.

[6] W. H. Willcox, "Acute Arsenical Poisoning," *Trans Medico-Legal Society*, 16 (1921–2), p. 178.

the sublimate is moistened with a minute drop of ammonium sulphide or sodium sulphide introduced into the tube by means of a capillary pipette or a very thin glass rod, an orange coloration of antimony sulphide may be seen if the edges of the drop are examined under the microscope. When the Marsh test is employed it is conducted in exactly the same manner as for arsenic. The antimony mirror formed in the heated tube differs from that of arsenic by being black and of a velvet or mat appearance, whereas the arsenic mirror is brown-black and glistening. If sulphuretted hydrogen, dried by means of strong sulphuric acid, is passed slowly through the tube and the deposit gently heated, an orange-red sulphide confirms the presence of antimony. Antimony mirrors are affected by moisture and light and therefore should be kept sealed and in the dark.

Antimony also may be deposited from solution electrolytically by means of zinc and platinum. For this purpose it is not necessary to destroy the organic matter. Strong hydrochloric acid is added to the material to be tested and a strip of platinum and a piece of zinc in contact with it are placed in the solution, or the acid solution is placed in a small platinum dish in which there is also a piece of zinc. If antimony is present, a black or brown-black deposit of metallic antimony will form on the platinum. The nature of this deposit may be confirmed by heating the foil in a sublimation tube and applying a drop of ammonium sulphide or sodium sulphide to the sublimate formed, when the orange-red sulphide of antimony will be produced.

When testing for antimony, if it is necessary to use rubber corks, these should on no account be red rubber, as this contains antimony compounds.

A modification of the Reinsch test elaborated by Beam and Freak for estimating small quantities of antimony is as follows[1]: The copper foil (working with 0·1 to 1·0 mgrm. of antimony about 1·5 cm. by 10cm.) is made into a coil and when deposition is complete this is taken out of the acid liquid by means of glass forceps, dropped into a large beaker filled with water, then without delay transferred to a boiling alkaline permanganate solution consisting of 15 c.c. of 1 per cent. potassium hydroxide solution and an amount of potassium permanganate solution (1 c.c. equals 0·01 grm. of iron) depending upon the quantity of antimony, which is indicated by the appearance of the deposit. For deposits of less than 0·3 mgrm. 0·5 c.c. of permanganate will suffice and the boiling should be continued for not more than 1 minute; for 0·5 mgrm. of antimony 1 c.c. of permanganate should be used and the boiling continued for 5 minutes or until the solution is decolorized; for about 1 mgrm. of antimony 2 c.c. of permanganate are required and the boiling carried out as for 0·5 mgrm. With very thin deposits, if the boiling is too long continued, there is danger of

[1] "The Estimation of Small Quantities of Antimony," *Analyst*, **44** (1919), pp. 196–9.

solution of copper from the strip. In all cases it is advisable to check the complete solution of the antimony by treating the copper with hydrochloric acid (1 : 5). If any black stain remains the strip is quickly washed with water and given a second treatment with alkaline permanganate. The liquid is poured off the strip, which is washed twice with water and the solution filtered through a small thick filter paper. A sufficient quantity of hydrochloric acid is then added to neutralize the alkali and to provide an excess of about 0·2 c.c. of strong acid. Sulphur dioxide is then passed through the solution for about 3 to 5 minutes and the liquid gently boiled until every trace of this sulphur dioxide is eliminated. A small piece of cotton thread is useful to regulate the boiling and it is advisable to carry the evaporation until not more than 10 c.c. of liquid remain. Cool, add 0·5 c.c. of 10 per cent. gum solution, make up to 25 c.c. and pass sulphuretted hydrogen until the colour is fully developed, which is usually in a few seconds. Comparison is made with a standard solution of antimony in the form of potassium antimony tartrate treated exactly in the same manner. Extremely consistent readings may be obtained with a Dubosq colorimeter. The success of the operation depends largely upon the complete extraction of the antimony in the solution by the copper strip, which in turn depends upon the time allowed for boiling, which with a volume of 50 c.c. containing 10 c.c. of concentrated hydrochloric acid and 0·5 mgrm. of antimony is complete in 1¼ hours Deposition takes place more slowly if less acid is present.

Bamford, commenting upon the Beam and Freak method, says[1]: "In expert hands this method gives consistent results and it was successfully employed in this laboratory . . . in carrying out some hundreds of determinations. . . . The technique is, however, somewhat intricate and there are difficulties which may lead to error in the hands of a worker not thoroughly familiar with the pitfalls." A much simplified colorimetric method is given "which has proved satisfactory provided that no metal of the second analytical group, other than antimony, is present." This is as follows: "A weighed sample of the tissue is cut up finely and mixed in a silica basin with sufficient magnesium oxide to give a definitely alkaline reaction. The material is then covered with a saturated solution of magnesium nitrate. In general 35 to 40 ml. of this solution are sufficient for 100 grams of animal matter. The mixture is then heated on a sand bath with frequent stirring until the material has dried, charred and begun to whiten. The charred mass may then be crushed with a pestle and afterwards heated more strongly, if necessary over a blowpipe flame. The ash should be quite white. If it is not, it may be cooled, mixed with a

[1] F. Bamford, "The Determination of Antimony in Viscera and Excreta," *Analyst*, 59 (1934), pp. 101–2. See also, F. Bamford, *Poisons: Their Isolation and Identification*, 1940.

concentrated solution of ammonium nitrate and reheated until free from nitrates. The ash when cold is moistened with water and sufficient hydrochloric acid is added to dissolve the magnesium oxide and to give a definitely acid reaction. The solution thus prepared is ready for analysis.

" Before the determination of antimony, however, it is necessary to remove iron. The solution is therefore diluted with distilled water and saturated with hydrogen sulphide. The precipitate is filtered off, washed . . . and dissolved in the minimum quantity of hot concentrated hydrochloric acid. The solution is diluted . . . re-filtered if necessary to remove fragments of filter paper and after the addition of gum arabic solution (1 ml. of a 5 per cent. solution being sufficient for 100 ml. of liquid), the solution is made up to a definite volume. Sulphuretted hydrogen is again passed through the liquid and the colour is compared in a Duboscq colorimeter with that of a standard approximately equal concentration." [1]

Antimony is best determined quantitatively by weighing the metal separated by electrolytic deposition, for which purpose the antimony is precipitated first as sulphide, which is filtered, washed and dissolved in sodium sulphide solution and then electrolysed.

Mercury. After arsenic, probably mercury is one of the most common poisons used. The compound principally employed for poisoning purposes is the perchloride (corrosive sublimate), which is used extensively as an antiseptic and hence is fairly easily procurable. As this compound is sold frequently coloured with a red organic dye, any such coloration in the stomach or stomach washings therefore may indicate the presence of mercuric perchloride.

Mercury may be tested for by the Reinsch test in the same way as arsenic and antimony. If mercury is suspected this should be confirmed by introducing the strips of copper foil into a sublimation tube the open end of which is drawn out into a capillary, care being taken to avoid heating the foil while doing this. The tube is now heated in the usual way, and if mercury is present the sublimate consists of minute globules of metallic mercury, which if examined with a lens cannot be mistaken. To confirm further the presence of mercury, a tiny particle of iodine is dropped into the tube and is heated gently, when the iodine vapour passing over the mercury forms the scarlet iodide, or the sublimate may be treated with a drop of strong nitric acid, warmed to drive off the excess acid, and then a drop of potassium iodide solution added when the scarlet iodide will be formed if mercury is present.

Mercury also may be determined by electrolysis in a solution slightly acid with nitric acid. A cathode of gold or platinum or heavily gilded

[1] The preparation of the standard solution is given, as also an example of an actual case in which the method was used.

platinum is used,[1] and care must be taken when subliming the deposit or when cleaning the electrode not to heat it too strongly, or the gold will fuse.[2] The nature of any deposit formed should be confirmed by sublimation with subsequent examination of the sublimate produced. Hargreaves and Rowe recommend [3] the following procedure: The gold or platinum foil used as the electrode is washed with water, then with alcohol, dried, rolled into a cornet and inserted into a tube (6×35 mm.), which is closed at one end and has an expanded mouth with the edges ground flat at the other. The open end is held against a microscope slide and the tube, which is fitted into a hole in a stout brass plate, is heated very gently. A sublimate of mercury will be obtained on the slide, where it can be examined. The heating must be carried out with care, otherwise the temperature may be too high and the mercury may be lost.

Traces of mercury too small for detection by ordinary methods may be deposited electrolytically and detected by spectroscopic examination.[4 5 6] For the quantitative determination of small quantities of mercury, Bamford recommends [7] the colorimetric comparison of the sulphide with solutions of sulphide precipitated from dilute standard solutions of mercuric chloride. The sulphide in the sample under test as first precipitated must be purified by treating it with hydrochloric acid and potassium chlorate and re-precipitating, the process being repeated if necessary until the solution before precipitation is colourless. The precipitates to be compared may be kept in suspension by the addition of a few drops of a solution of gum arabic.[8]

Calomel exposed to ultra-violet rays "exhibits a brilliant salmon-pink luminescence." [9]

Copper and Lead. The residue from the extraction of alkaloids may be used to test for general metallic compounds such as those of copper and lead. The organic matter present is burnt off and the ash extracted repeatedly with strong nitric acid, washed, filtered and the solution obtained tested in the usual way.

[1] Before use this must be heated to expel traces of mercury derived from the laboratory atmosphere, which usually is contaminated with mercury vapour.

[2] An inexpensive and simple apparatus is described by Colles (W. M. Colles, in *The Practice of Medicine in the Tropics*, edited by W. Byam and R. G. Archibald, **1**, 1921, pp. 825–6).

[3] W. A. Hargreaves and W. T. Rowe, "The Detection of Mercury in Explosives," *Journ. Soc. Chem. Ind.*, **26** (1907), p. 813.

[4] K. C. Browning, "The Detection of Mercury Salts for Toxicological Purposes," *Journ. Chem. Soc. Trans.*, **111** (1917), pp. 236–40.

[5] Naoum, "Spectroscopic Identification of Mercury," *Analyst*, **49** (1924), p. 348.

[6] A. J. Pacini, "Ultraviolet Spectrographic Detection of Mercury," *The American Journal of Police Science*, **1** (1930), pp. 387–95.

[7] F. Bamford, *Poisons: Their Isolation and Identification*, pp. 101–103.

[8] See also C. Newcomb, S. Rajagopal Naidu and K. S. Varadachar, "The Determination of Mercury in Viscera," *Analyst*, **60** (1935), pp. 732–35.

[9] F. W. Martin, *Analyst*, **59** (1934), p. 531.

The presence of copper is of no forensic significance unless the amount is large, as copper compounds frequently occur normally in the human body. Any positive qualitative test, therefore, should be followed by a quantitative determination, the best method being that by electrolysis.

" An accurate and comparatively simple method " for the determination of lead in bones and other biological material has been published. " The process involves wet oxidation (instead of ashing), followed by diphenylthiocarbazone extraction of the lead and subsequent colorimetric determination as sulphide."[1] [2] [3]

Poisons Requiring Special Methods of Extraction

The most important are oxalic acid and oxalates, which not infrequently are employed as poisons in England.

Oxalic Acid and Oxalates. The best method of separating oxalic acid and oxalates from the stomach contents or from vomit is by digestion with hydrochloric acid, and as carried out by Elsdon and Stubbs [4] the process is as follows: A suitable quantity of the material, diluted with water if necessary, is centrifuged for several minutes, decanted as completely as possible and the residue broken up with a glass rod, mixed with a quantity of water equal in bulk to the original volume of liquid and again centrifuged and the liquid decanted and mixed with the first decanted portion. In general the residue will be free from oxalic acid and oxalates but it should always be treated with hydrochloric acid and tested. The solution is mixed with 15 to 20 per cent. of strong hydrochloric acid and heated on the water bath for about two hours, filtered and the residue well washed with water. The mixed filtrate and washings are made alkaline with ammonia (0·880). and then acid with concentrated acetic acid and precipitated with calcium chloride [5] in the usual manner. The precipitate is always coloured and a second or even a third precipitation may be necessary, which is done by making a hole in the filter paper, washing the precipitate into a beaker, dissolving it in hydrochloric acid with the aid of heat and reprecipitating. The precipitate is dried at 100° C. and weighed. To confirm, dissolve in hot dilute sulphuric acid and titrate with deci-normal permanganate solution.

Qualitative Tests for Oxalic Acid. An organic acid that reduces permanganate and that gives a precipitate with calcium chloride, insoluble

[1] G. Roche Lynch, R. H. Slater and T. G. Osler, " The Determination of Traces of Lead in Biological Materials, with Special Reference to Bone," *Analyst*, 59 (1934), pp. 787–806.
[2] D. C. Garratt, *Analyst*, 60 (1935), p. 817.
[3] L. Ellis, *Analyst*, 61 (1936), pp. 178–179.
[4] G. D. Elsdon and J. R. Stubbs, " The Detection and Determination of Oxalic Acid and Oxalates in Stomach Contents," *Analyst*, 55 (1930), pp. 321–2.
[5] Wynter Blyth precipitates with calcium acetate (A. Wynter Blyth and M. Wynter Blyth, *Poisons: Their Effects and Detection*, 1920, p. 550).

in acetic acid, is not necessarily oxalic acid, but may be tartaric acid. When precipitated in dilute solution containing acetic acid, however, oxalates give an immediate precipitate in the cold, whereas tartrates do not give a precipitate until the solution is shaken or allowed to stand. Silver nitrate produces a white precipitate, soluble with difficulty in dilute nitric acid, but easily if the acid is hot and strong ; it is also soluble in ammonia solution. Barium chloride gives in neutral solutions of oxalates a white precipitate of barium oxalate. Oxalates of the alkali and alkaline earth metals when ignited are converted into carbonates with very slight separation of carbon. When an oxalate in the dry condition is heated with strong sulphuric acid it is decomposed with the formation of carbon monoxide and carbon dioxide, the latter of which is recognized readily by its action on lime water.

Arnaud and Flint [1] state that since oxalic acid in presence of free hydrochloric acid is slightly soluble in ether, an ethereal extraction process may be used in certain cases for the qualitative testing for oxalic acid. They also point out that the crystals of precipitated calcium oxalate are characteristic and therefore that they should always be examined microscopically.

The presence of a trace only of oxalate is without significance in forensic cases as it may be due to natural causes.

Carbon Monoxide.

Carbon monoxide is a colourless, tasteless, odourless, highly poisonous gas that occurs in illuminating gas, in power gas and in the exhaust gas of petrol engines ; it is formed when carbon is burned with a deficient supply of air. In ordinary coal gas, carbon monoxide may be present in the proportion of from about 4 to about 12 per cent. ; in illuminating gas, when this consists of a mixture of coal gas and water gas (as is often the case) it occurs in varying proportions up to about 20 per cent. ; in water gas it is present up to nearly 40 per cent. and in the exhaust gas of petrol engines, as for instance in that of motor cars, it occurs in the proportion of about 7 per cent. Carbon monoxide is a cumulative poison and fatal results follow the inhalation of air containing very small proportions if continued for a considerable time ; air containing 1 per cent. is rapidly fatal.

Carbon monoxide is a blood poison and when inhaled it displaces the unstable oxygen of the oxyhæmoglobin of the blood, forming carboxyhæmoglobin which imparts to the blood a bright red colour.

Tests for Carbon Monoxide in Blood.

1. The simplest method of detecting carbon monoxide in blood is by comparison of the suspected blood with normal blood when both are diluted with water in the proportion of one part of blood to 100 parts of water. In such dilution normal blood appears yellow and carbon monoxide blood pink.

[1] F. W. F. Arnaud and J. W. Flint, *Analyst*, 55 (1930), p. 501.

2. Dilute a little of the blood to be tested with four times its own volume of water and add three times the original volume of the blood of a 1 per cent. solution of tannic acid in water, shake well and allow to stand. Carbon monoxide blood forms a permanent light red precipitate, while normal blood, although red at first, becomes brown after from about one to two hours and grey in from 24 to 48 hours.

3. Dilute the blood to be tested with 20 times its own volume of water and add an equal volume of a 30 per cent. solution of caustic soda. Carbon monoxide blood at first gives a milkiness and then becomes light red, whereas normal blood becomes dirty brown.

4. Mix 15 c.c. of the suspected blood with an equal volume of 20 per cent. potassium ferrocyanide solution and 2 c.c. dilute acetic acid (1 vol. glacial acid + 2 vols. water) and shake gently until the mixture coagulates. In the presence of carbon monoxide the colour will be bright red, whereas with normal blood it is dark brown.

Tests for Carbon Monoxide in Air.

1. A simple and delicate test is to pass a volume of the air to be tested through a neutral aqueous solution of palladous chloride, which is of a light red colour and from which black metallic palladium is precipitated if carbon monoxide is present. A drawback of the test is that sulphuretted hydrogen, ammonia and certain hydrocarbons present in coal gas all give the same reaction. Sulphuretted hydrogen and ammonia may be removed by passing the air through solutions of lead acetate and dilute sulphuric acid respectively before testing it with the palladous chloride. A useful variation of the test is to expose to the suspected air strips of paper impregnated with palladous chloride.[1] If blackening does not occur the air is free from carbon monoxide (and also from sulphuretted hydrogen and ammonia) and hence the absence of blackening provides a good negative test.

2. A mixture of pumice stone, iodine pentoxide and fuming sulphuric acid (termed Hoolamite) reacts with carbon monoxide to give a green colour that varies in depth of tint with the concentration of the gas.

Quantitative Determination of Carbon Monoxide.

1. The simplest approximate quantitative method for carbon monoxide in blood is the colorimetric one of Haldane.[2] [3] For the purpose of the test three small tubes are taken; in (*a*) is placed a 1 per cent. solution of the

[1] Pratt (J. Davidson Pratt, *Protection against Toxic Gases in Industry*, 1936, p. 15) states that "The impregnating solution is made by boiling 0·1 gram of palladium chloride for a few minutes in approximately 20 c.c. of distilled water. The mixture is filtered and the filtrate cooled and made up exactly to 20 c.c. with distilled water; 20 c.c. of acetone are added and the mixture stirred, when it is ready for use.

[2] *Journ. of Physiology*, **18** (1895), pp. 430, 465; **20** (1896), p. 521.

[3] J. S. Haldane, "Carbon Monoxide Poisoning," *Trans. Medico-Legal Society, London*, **24** (1929-30), pp. 156–81.

blood to be tested,[1] in (*b*) is placed a 1 per cent. solution of normal blood,[1] and in (*c*) is placed a 1 per cent. solution of normal blood saturated with carbon monoxide. Add to (*b*) a 0·01 per cent. solution of carmine [2] until its tint is the same as that of (*a*), note the amount required and continue the addition of carmine until the tint is the same as that of (*c*) and again note the amount required. From these data the amount of carbon monoxide in the blood may be calculated.

2. Another method for the quantitative determination of carbon monoxide in blood is that of Van Slyke and Neill [3] or this method as modified by Harington and Van Slyke,[4] in which the gases are extracted from the blood in a vacuum ; the carbon dioxide and oxygen absorbed by suitable reagents ; the carbon monoxide and nitrogen measured together ; the former then absorbed by means of cuprous chloride and the residual nitrogen measured and the volume of carbon monoxide found by difference.

3. A method for both the detection and determination of carbon monoxide in blood, which is stated to be simple, accurate and inexpensive, is described by Christman and Randall and is based on the reduction of palladous chloride and the determination of the excess palladous chloride colorimetrically.[5] A method based on the same principle for the determination of carbon monoxide in air is described.[6]

4. For the quantitative determination of carbon monoxide in air, either the palladous chloride method or the Hoolamite method may be used in the form of recorders, the amount of carbon monoxide being ascertained from the colour produced by reference to a standard colour scale.[7] [8] The results however are only approximate. An accurate determination may be made by means of palladous chloride by first freeing the air from sulphuretted hydrogen and ammonia by means of lead acetate and dilute sulphuric acid and then separating, washing, drying and weighing the metallic palladium precipitated, from which the amount of carbon monoxide may be calculated,

[1] 0·02 c.c. diluted with 2 c.c. of water.

[2] Made by mixing 1 gram pure carmine with a few drops of ammonia in a mortar and dissolving it in 100 c.c. of glycerine. For use 5 c.c. of this solution is diluted to 500 c.c. with distilled water : 6 c.c. carmine + 5 c.c. blood diluted to 1 per cent. = 1 per cent. blood saturated with carbon monoxide.

[3] D. D. Van Slyke and J. M. Neill, " The Determination of Gases in Blood and Other Solutions by Vacuum Extraction and Manometric Measurement," *The Journ. of Biological Chemistry*, **61** (1924), pp. 523–73.

[4] C. R. Harington and D. D. Van Slyke, " The Determination of Gases in Blood and Other Solutions by Vacuum Extraction and Manometric Measurement," *The Journ. of Biological Chemistry*, **61** (1924), pp. 575–84.

[5] A. A. Christman and E. L. Randall, " Method for the Determination and Detection of Carbon Monoxide in Blood," *Journal Biol. Chem.*, **102** (1933), pp. 595–609 ; *Analyst*, **58** (1933), pp. 769–70.

[6] A. A. Christman, D. Bloek and J. Schultz, " Determination of Carbon Monoxide in Air," *Industrial and Engineering Chemistry*, **29** (1937), pp. 153–156.

[7] C. L. Turner, " Special Equipment for Protection against Toxics in the Chemical Laboratory," *Ind. and Eng. Chemistry*, **22** (1930), pp. 1096–9.

[8] C. R. Hoover, *Ind. and Eng. Chemistry*, **13** (1921), pp. 770–2.

or either by the method of Van Slyke and Neill or by that of Harington and Van Slyke, as used for carbon monoxide in blood.

According to Ambler and Sutton carbon monoxide in air can be detected in proportions as low as 0·015 per cent. by the palladous chloride method ; in proportions as low as 0·004 per cent. by the Hartridge Reversion Spectroscope and in proportions as low as 0·0005 per cent. by the iodine pentoxide (Hoolamite) method, which latter they recommend for routine use.[1]

5. *Spectroscopic Method.* Although carboxyhæmoglobin gives a well defined spectrum, this is much too like that of oxyhæmoglobin to be relied upon in forensic cases (unless examined as described later), both spectra consisting of two bands situated between the D and E lines of the solar spectrum, the bands of carboxyhæmoglobin, however, being very slightly closer together and very slightly nearer the violet end than those of oxyhæmoglobin. In spite of the close similarity the two spectra there would not be any difficulty in establishing their identity if either were present alone, since reducing agents, such as ammonium sulphide, have no action upon carboxyhæmoglobin (the spectrum of which therefore remains the same after treatment as before), but reduces oxyhæmoglobin, with the result that the two separate bands of the spectrum disappear, giving place to one single broad band. But in cases of carbon monoxide poisoning death occurs before the whole of the oxyhæmoglobin of the blood becomes converted into carboxyhæmoglobin and therefore both compounds are present and the spectrum of such blood is a composite one formed by the overlapping of the two separate spectra ; only two bands are seen and the difference between their position and that of the bands of oxyhæmoglobin of normal blood is too slight to afford convincing evidence in forensic cases. After treatment with ammonium sulphide what is seen may be either the one board band of reduced hæmoglobin or the two bands of carboxyhæmoglobin with the space between them dimmed by the broad band, according to the respective proportions of oxyhæmoglobin and carboxyhæmoglobin present.

The only satisfactory spectroscopic method of examining blood suspected to contain carbon monoxide is by means of the Hartridge Reversion Spectroscope, whereby the percentage saturation of blood with carrbon monoxide is determined by the wave-length measurements of its absorption bands.[2] This method, which is reliable, simple and rapid, has been described by Frederick [3] and Smith and Glaister.[4]

[1] H. R. Ambler and T. C. Sutton, " Detection of Traces of Carbon Monoxide in Air," *Nature*, 27th May, 1933, p. 766.

[2] H. Hartridge, " The Coincidence Method for the Wave-Length Measurement of Absorption Bands," *Proc. Roy. Soc.*, A, **102** (1923), pp. 575–87.

[3] R. C. Frederick, " Carbon Monoxide Poisoning : Its Detection and the Determination of the Percentage Saturation in Blood by means of the Hartridge Reversion Spectroscope," *Analyst*, **56** (1931), pp. 561–71. Also " The Hartridge Reversion Spectroscope for the Examination of Blood," *Analyst*, **62** (1937), pp. 452–454.

[4] Sydney Smith and J. Glaister, *Recent Advances in Forensic Medicine*, 1939.

As pointed out by Haldane,[1] the blood after death from nitrite poisoning becomes red, owing to the formation of nitric-oxide-hæmoglobin, which when present in the corpuscles has a similar red colour to that of oxyhæmoglobin and carboxyhæmoglobin and also has a similar double-banded spectrum, though less sharply defined. Haldane gives the following method of distinguishing between them. " On boiling a solution of NO-hæmoglobin a pinkish colour remains in the precipitate ; whereas with CO-hæmoglobin the colour becomes grey, as with oxyhæmoglobin. The tint of a diluted solution is also pinker than a corresponding solution of oxyhæmoglobin, but not nearly so pink as a solution of CO-hæmoglobin."

Hashish (Indian Hemp).

This subject is included not only on account of the fact that many criminals in the East are confirmed hashish takers and crime committed under the influence of hashish is not uncommon, but also because hashish may be employed directly for criminal purposes.

Hashish is the Arabic term for grass, weed or herbage generally, but in addition to this meaning the word has acquired a special and narrower signification, and is applied to a particular plant, the Indian hemp (*Cannabis indica*), and to preparations made from it.

In temperate climates hemp is grown for its fibre and seed, and possesses no pharmacological interest whatever, but in warm countries it develops a resinous secretion upon its leaves and flowering heads, and this when smoked or swallowed induces marked derangement of the nervous system. *Cannabis indica*, however, which is the hemp grown in Northern India, Turkestan, Persia, Syria, Arabia, in many parts of Africa, in Greece and in Brazil, is identical botanically with the ordinary hemp *Cannabis sativa* of temperate climates. The intoxicating and narcotic properties of Indian hemp have been known in the East from a very early period, and are referred to by both Herodotus and Galen.

As ordinarily used in Egypt, the word hashish means the resinous material from the plant, containing a certain amount of leaf tissue and mineral matter,[2] the whole compressed into a hard cake. Hashish as thus defined corresponds to the Indian " Charas." The Indian " Bhang " and " Ganja " also are derived from hemp, Bhang consisting of the dried and broken leaves and small stalks of the plant, together with a few fruits, the whole being in the

[1] J. S. Haldane, *op. cit.*, pp. 165–7. See also J. A. Gardner and G. A. Buckmaster. " Hæmoglobin and its Derivatives," *Allen's Commercial Organic Analysis*, **10** (1933). pp. 46–7.

[2] The mineral matter in various samples examined ranged from 24 to 58 per cent. It is not known to what extent this indicates adulteration, but in addition to the mineral matter present in the plant tissue, a certain amount accumulates on the plant during growth owing to the sticky nature of the resinous secretion and additional dust and dirt gain access during drying, preparation and packing.

form of a coarse powder, while Ganja is the flowering and fruiting tops of the female plant compressed into bundles.

Hashish is used in three different ways and may be smoked, eaten or drunk, smoking and eating, however, being the usual modes of consumption. When smoked, the drug is mixed with tobacco and used either in a water pipe or in cigarettes. In samples of cigarettes examined the amount of hashish has varied from 7 to 16 per cent. of the net weight of the tobacco. When present in cigarettes hashish is detected readily, since it is introduced either in the form of small pellets or more generally in thin strips. If no visible hashish is found, the tobacco should be tested, since it is quite conceivable that it might have been soaked in an alcoholic solution of hashish. The author has never known a case where this particular method of introducing hashish into tobacco has been employed, but he once examined a strong alcoholic solution of hashish seized by the Customs, that could well have been used for such a purpose.

For eating, hashish is mixed with spices and made into a paste with sugar, honey, molasses or fat, or it is introduced into sweetmeats. The paste is taken in the form of pills. When required for the use of excessive consumers to whom hashish alone is no longer sufficient, it is stated that sometimes opium or datura seeds are added.

Tests for Hashish. The tests for hashish are microscopical and chemical. The microscopical identification of particles of the hemp leaf when present is the most reliable test. The special features of the leaf tissue that are characteristic and that therefore should be searched for are the glands, the gland stalks, the simple hairs and the crystolithic hairs.[1] Before the introduction of Beam's test [2] [3] the only way of detecting hashish apart from the microscopical recognition of any leaf tissue present, was by the characteristic smell, the usual procedure being to extract the suspected substance with some solvent such as alcohol, ether or petroleum spirit, to evaporate off the solvent, and to note the smell of the dried extract while warm. Such a test, however, is not satisfactory even at its best, and it fails entirely when the hashish is present in small amount, or if it is mixed with spices or other odoriferous ingredients, a not unusual condition. Beam's test is as follows: "The suspected material is extracted with petroleum ether [4] of low boiling point and which leaves no perceptible residue when evaporated in the cold. If solid, the material should, if possible, be powdered finely previous to

[1] H. G. Greenish and E. Collin, *An Anatomical Atlas of Vegetable Powders*, 1904, p. 101.

[2] W. Beam, *Wellcome Tropical Research Laboratories*, Fourth Report, Vol. B, pp. 25–6. Khartoum, 1911.

[3] W. Beam, *Wellcome Tropical Research Laboratories, Chemical Section, Bulletin* No. 3, April, 1915. Khartoum.

[4] When fatty material is present, alcohol is a better solvent to use than petroleum ether, since it does not dissolve the fat.

the extraction ; or if soluble in water the solution may be shaken out with petroleum ether. The petroleum ether extract is separated, passed through a filter and evaporated to dryness in a small porcelain capsule. Both extraction and evaporation should be carried out in the cold. . . . To the residue a few drops of weak alcoholic solution of potash or soda (about deci-normal strength) are added, and the liquid allowed to evaporate at room temperature. In the presence of hashish a rich purple or reddish purple colour gradually develops which on dilution with water takes a more bluish cast. It is very permanent." This gradual development of the colour, which is due to the oxidation of the colourless compound first formed, is an important feature of the test.

It has been found, however, that genuine preparations of *Cannabis indica* such as Ext. Cannabis Ind. B.P. and Merck's purified alcoholic extract, both of which are made by extraction with alcohol accompanied by prolonged heating, as also very occasionally a genuine hashish plant,[1] fail to respond to this test, and Beam devised a modified test, which is as follows : " The petroleum ether extract is made as usual, and the evaporation of the solvent is carried out in a short test tube. To the residue is added a few cubic centimetres of a reagent prepared by passing dry hydrogen chloride gas through absolute alcohol to saturation. In the presence of *Cannabis* extract the liquid strikes a bright cherry-red colour, which disappears on dilution with alcohol or water." [2]

A modification of Beam's test, which has been in use in the Government Laboratory, London, for many years has been published by Nickolls.[3] This is stated to be very sensitive and very few substances (myrrh and guaicum being among the few) interfere. I frequently have employed the original test, and have found it satisfactory, but I have had very little experience of the modified test, and so cannot criticize it.[4] Colles says, " I have not found this modification of much value." [5]

With reference to the second test, which Beam merely calls " a useful presumptive test," he states that " Trials have been made with a number of plant extracts and over 200 alkaloids, glucosides, etc., but in no case was a similar reaction obtained. Many of these are of course eliminated by the preliminary solution in petroleum ether. Certain volatile oils, e.g. origanum and santal, give a similar reaction, but the colour is far less intense for similar amounts of material."

[1] The plants that failed to respond may have been young and the resinous material not yet developed.

[2] W. Beam, *Wellcome Tropical Research Laboratories, Chemical Section, Bulletin* No. 3, April, 1915. Khartoum.

[3] L. C. Nickolls, " Notes on Beam's Test for Hashish (Indian Hemp)," *Analyst*, 61 (1936), p. 604.

[4] See F. Bamford, *Poisons : Their Isolation and Identification*, pp. 326–330.

[5] W. M. Colles, *op. cit.*, p. 813.

I found [1] that the following-named substances failed to respond to the first test, namely, anise, banana leaf, cardamoms, carraway seed, cascarilla, cinnamon, cloves, colcass leaf, datura leaves and seeds, ergot, fennel, maize fibre, mint, nutmeg,[2] opium, rose leaves, saffron, thyme and tobacco.

Trolle [3] tried both of Beam's tests with the following-named: alkanet, cinnamon, cloves, coriander, black currant, fennel, ginger, liquorice, majoram, nutmeg, pyrethrum, thyme and wormwood, and states that alkanet responded to the tests, that majoram did not respond and that a mixture of alkanet and majoram responded as also did a mixture of all the other substances enumerated, except alkanet.

Rende [4] states that cinnamon and also a mixture of alkanet, cinnamon, cloves, cochineal, coriander, majoram and nutmeg responded to Beam's first test.

The results of Trolle's and Rende's results, however, merely show that alkanet, cinnamon and one at least of the other substances mentioned gave the Beam test, while the others may or may not have responded.[5]

It is stated that the examination by means of ultra-violet rays of a petroleum spirit extract of a suspected substance or mixture may enable hashish to be detected.[6]

Hashish is used principally on account of its reported virtues as an aphrodisiac.

From time to time a number of attempts have been made to isolate the active principle of Indian hemp, but this has not yet been done; it has been proved, however, that this principle is contained in a resin and that it is not an alkaloid.[7]

Illustrative Cases. The best illustrative cases of poisoning are the well-known ones, particulars of which are published in the Notable Trials Series. In only four cases, however, namely that of Dr. Pritchard, that of E. M. Chantrelle, that of Madeleine Smith and that of Neill Cream, are copies of the chemical reports given. It would be most helpful if the editors of all such trials gave a full copy of the chemical report, since the details of the chemical analysis are somtimes difficult to follow from the evidence. In several cases too there are manifest misprints and mistakes in the transcription of the chemical evidence.

[1] A. Lucas, "Some Notes on Hashish," *Cairo Scientific Journal*, 5 (1911), p. 154

[2] With nutmeg a slight pink colour was at first obtained, which, however, was not permanent and rapidly became reddish-brown.

[3] H. Trolle, *Contribution à l'Analyse des Substances Toxiques et des Stupéfiants*, 1932, p. 13.

[4] G. Rende, in *Trolle's paper*, p. 19.

[5] A. Lucas, "Beam's Colour Test for Hashish," *Analyst*, 58 (1933), p. 602.

[6] J. Khouri, "Use of Filtered Ultra-Violet Radiation in the Examination of Hashish in the Pure State or Mixed with Various Drugs," *Ann. Falsif.*, 1935, 28, pp. 582–584; *Analyst*, 61 (1936), pp. 213–214.

[7] R. S. Cahn, "Cannabis Indica Resin," *Journal Chemical Society*, 1930, 1, pp. 986–92; 1931, 1, pp. 630–8; 1932, 1, pp. 342–53.

The nature of the poison and the amount found in a number of the best known poisoning cases is given in the following table :

Nature of Poison.	Amount Found.	Case.	Date.
Aconitine	. . . . .	Dr. Lamson	1882
Antimony	0·5 grain antimony. Strychnine also suspected but not found.	Dr. Palmer	1856
Antimony	Victim (*a*). More than 2·55 grains calculated as metallic antimony (6·9 grains as tartar emetic) : also mercury. Victim (*b*). More than 0·68 grain calculated as metallic antimony (1·8 grains as tartar emetic).	Dr. Pritchard	1865
Antimony	Victim (*a*). 10·12 grains calculated as tartar emetic. Victim (*b*). 29·12 grains calculated as tartar emetic. Victim (*c*). 3·83 grains calculated as tartar emetic.	G. Chapman	1903
Arsenic	More than 87·9 grains calculated as arsenic trioxide in stomach contents alone.	Madeleine Smith	1857
Arsenic	About 0·5 grain as arsenic trioxide.	Mrs. Maybrick	1889
Arsenic	Total arsenic calculated as trioxide in whole body, 2·01 grains.	The Seddons	1912
Arsenic	0·28 grain as trioxide.	H. Greenwood	1920
Arsenic	3·21 grains calculated as arsenic trioxide.	H. R. Armstrong	1922
Hyoscine	0·285 grain.	H. H. Crippen	1910
Opium	No poison in body : opium on a sheet and bed gown.	E. M. Chantrelle	1878
Strychnine	Victim (*a*). 6·75 grains strychnine. Victim (*b*). 3·26 grains strychnine. Victim (*c*). 0·062 grain strychnine.	Neill Cream	1892

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CHAPTER XIV

PRESERVATION OF THE HUMAN BODY AFTER DEATH

ON first thoughts this subject might appear to be neither of any forensic importance nor chemical, but, as will be shown, sometimes it may be both.

Preservation. Death, as a rule, is followed by putrefaction, largely caused by micro-organisms, and when allowed to proceed to its full extent, ends with the entire disappearance of the soft parts of the body, which are resolved into simple inorganic compounds. Putrefaction, however, may be prevented or delayed. Thus desiccation preserves the body and a number of cases are known of the preservation of the bodies of newly-born children brought about by their having been kept in warm dry places. As an example of an artificial method of preservation, in which desiccation played the principal part, mummification as practised in ancient Egypt may be mentioned,[1] the preservation being aided by the removal of the viscera, which removal must have been a considerable factor in the prevention of bacterial decay. But, apart altogether from mummification, and dating from a period long before it was known, there are in Egypt, and in other dry countries, numerous examples of well preserved bodies that have been desiccated by natural means and owe their preservation to burial without coffins in shallow graves in hot, dry sand, thus allowing heat to penetrate and the moisture from the body to escape.

Adipocere. The formation of adipocere, which is a waxy-looking solid having a greasy feel, that is found frequently in bodies that have been buried in damp soil or submerged in water for a considerable time, is an example of delayed putrefaction. Adipocere, as proved by its chemical composition,[2-8] is composed essentially of saturated fatty acids, largely palmitic, but containing stearic and hydroxy-stearic acids, and is formed from the fat pre-existing in the body. Material occurring as a white efflorescence on mummies has been found by me to be of similar composition and to consist of fatty acids, derived doubtless from the body fat.

[1] A. Lucas, "The Use of Natron in Mummification," *Journal of Egyptian Archaeology*, 18 (1932), pp. 125–40.

[2] J. Lewkowitsch, *Chemical Technology and Analysis of Oils, Fats and Waxes*, 1914, p. 687.

[3] L. van Itallie and A. J. Steinhauer, *Chemical Abstracts*, 1917, p. 1437.

[4] R. F. Ruttan and M. J. Marshall, *Journ. Chem. Soc.*, **112** (1917), Abst. I, p. 364.

[5] R. F. Ruttan, *Journ. Chem. Soc.*, **112** (1917), Abst. I, p. 495.

[6] S. Goy and E. Wende, *Chemical Abstracts*, **17** (1923), p. 1484.

[7] G. Strassmann and Fantl, *British Chem. Absts.*, 1926, A., p. 752.

[8] S. Goy, *British Chem. Absts.*, 1927, A., p. 987.

Effect of Lime on the Body. Not infrequently in murder cases in which the body is buried lime is employed, either in the hope of hastening decomposition or of preventing the offensive products of putrefaction from manifesting themselves. Thus in both the Manning[1] and Crippen[2] cases lime was used and "chloride of lime" in the Wainwright[3] case.

Before discussing this subject it should be stated that the word "lime" as ordinarily used may mean either quicklime or slaked lime or even chlorinated lime (bleaching powder), frequently called "chloride of lime." Quicklime is calcium oxide produced by strongly heating limestone; as ordinarily made for building purposes it is in the form of large irregular lumps. Slaked lime is calcium hydroxide, a dry white powder obtained from quicklime either by exposing this latter to a moist atmosphere or by the addition of water. In both events heat is produced, but in the former the reaction proceeds so slowly that the effect is small, the heat being dissipated almost as quickly as it is formed, whereas when water is added to quicklime a large amount of heat is evolved, which may be sufficient to ignite combustible bodies in contact with the lime.[4] Chlorinated lime is a product of the action of chlorine gas upon slaked lime and is employed extensively as a disinfectant. It soon loses its efficiency if exposed to the air. The name "chloride of lime" for this substance, although in common use, is not only ambiguous but incorrect, dry chlorinated lime consisting chiefly of a substance intermediate between calcium chloride and calcium hypochlorite.

During the Manning trial it was stated by a witness that lime would cause a dead body to decompose more rapidly[5]; in the Crippen case it was stated in evidence that quicklime destroys flesh and that given a sufficient quantity the whole body would be destroyed.[6] Both these statements, however, although in accordance with a very prevalent belief, are contrary to fact. If a dead body is surrounded by a large amount of quicklime and if this is slaked suddenly, as was done in the Manning case, a small amount of superficial burning will result and a certain amount of drying of the body, caused by the heat generated, will take place, the extent of both of which depending upon the amount and quality of the quicklime used and upon whether or not there are clothes or wrappings on the body. The body, however, will not be destroyed, or even partially destroyed, but the drying, by delaying putrefaction, will conduce to preservation. If only gradual

[1] F. J. Smith, *Taylor's Principles and Practice of Medical Jurisprudence*, **1**, 1920, p. 294.
F. Young, *Trial of H. H. Crippen*, 1920, p. 45.
H. B. Irving, *Trial of the Wainwrights*, 1920, pp. 24, 27.
See p. 192.
F. J. Smith, *Taylor's Medical Jurisprudence*, **1**, 1920, p. 294.
F. Young, *Trial of H. H. Crippen*, 1920, p. 58.

slaking of the lime takes place by means of water abstracted from the body, or from the surrounding soil, and this is the condition assumed in the Crippen case, then again there will be partial desiccation with the consequent delayed putrefaction. The lime in both cases will tend to preserve the body from destructive agencies from without. Lime, however, which is used in the form of milk of lime in the dehairing of hides may cause the hair to fall off.

In order to obtain positive evidence of the nature of the action of lime on the dead body, as no record could be found of any work on the subject, the following-mentioned experiments were made. Young pigeons were killed and plucked but not opened, nothing being removed but the feathers, and were then treated separately as follows :

A. Buried in dry earth.
B. Buried in freshly slaked and sifted lime.
C. Buried in fresh chlorinated lime.
D. Buried in quicklime in the form of small lumps.
E. Buried in quicklime in small lumps which was suddenly slaked by the addition of water.

In all cases the burials took place in boxes provided with loosely fitting covers that were placed on the laboratory roof in Cairo in July. After twenty-four hours, specimen E was taken out and examined. The lime was in the condition of a dry white powder and the pigeon was somewhat discoloured, considerably drier and firmer than originally, but no blistering or rupture of the skin or other damage caused by the heat except discoloration could be found. The pigeon was re-buried in the same slaked lime. After three days pigeon C was found to be partly uncovered owing to the considerable swelling caused by putrefaction that had taken place ; there was a most objectionable smell and the chlorinated lime had become wet and pasty. The pigeon was reburied in the same wet lime. After five days a number of large maggots and several small beetles were visible in box A and the smell was very disagreeable. After fifteen days all the pigeons were disinterred and examined, when the following results were found :

A. Active decomposition taking place : disagreeable smell.
B. No visible decomposition : some smell : still soft.
C. Decomposition proceeding : smell very objectionable : chlorinated lime pasty.
D. Lime all slaked : pigeon dry and intact (not quite so dry as E) : no burning or rupture of the skin.
E. Dry and firm : slight discoloration but no rupture of the skin.

The pigeons were re-buried and left for a further period of five and a half

months, making six months altogether, when they were re-examined, and the experiments discontinued. The results were as follows :

A. In very bad condition : considerable smell of putrefaction : large part of flesh had disappeared.

B. In good condition : very slight smell : shrunken : flesh still soft and skin pliable : skin unbroken.

C. In active state of decomposition : swollen : considerable smell of putrefaction.

D. In good condition : dry and hard : skin unbroken : shrunken.

E. In good condition except the feet, both of which had come off : dry, hard and brittle : skin unbroken : shrunken.

These results confirm the statements made, namely first, that the lime is a preservative, and second that the act of slaking lime in contact with a dead body, whether this is brought about gradually or done suddenly, does not destroy the body.

Hair.[1] Since the colour of the hair of a dead body of an unknown person, whether death be due to accident or to crime, may be a factor in the identification of the person, as it was in both the Crippen [2] and Eyraud and Bompard [3] cases and, since it has been stated that all hair of the dead eventually becomes red, owing to the disappearance of the colouring matter and the oxidation of the iron compounds present, it becomes necessary to determine whether there is any basis of fact for such a statement. As an example of this alleged change of colour, the case of Petrarch is cited.[4] Petrarch died at the age of seventy, but from the age of twenty-five his hair was white and it is recorded that many years after his death, when his coffin was broken open by robbers in search of treasure, the hair was then red. Wilkinson in his description of women's hair in ancient Egypt, writes [5] : " Many of the mummies of women have been found with the hair perfectly preserved . . . the only alteration in its appearance being the change of its black hue, which became reddened by exposure to great heat during the process of embalming." There is no proof, however, that the body was subjected to great heat during embalming, and, so far as is known, it was not, but even if this were so, it cannot be admitted that the hair of Egyptian mummies is always or even often red, for this is certainly not so. Most of the hair of the very large number of mummies seen by me has been either black or brown, though in several instances there was a slight reddish tint, but none of the hair was definitely red, and of the ancient Egyptian wigs examined none

[1] See also pp. 155–7.
[2] F. Young, *Trial of H. H. Crippen*, pp. 47, 49, 50.
[3] H. B. Irving, *A Book of Remarkable Criminals*, 1918, p. 307.
[4] E. J. Mills, *The Secret of Petrarch*, 1904.
[5] J. G. Wilkinson, *The Ancient Egyptians*, **2**, 1890, p. 335

has been red or even reddish,[1] and in a few experiments I made in which specimens of human hair (both black and brown) were buried in quicklime and in solid natron respectively, and were allowed to remain undisturbed for a period of four years and four months, there was not any perceptible change of colour.

During the Archæological Survey of Nubia a very large number of bodies were examined carefully and described by Professor (Sir Grafton) Elliot Smith and Dr. F. Wood Jones.[2] These bodies belonged to all periods varying from predynastic to early Christian. In the published report reference is made to the hair in 128 different cases and in no single instance is it described as red or even reddish.

In the catalogue of royal mummies in the Cairo Museum, Professor (Sir Grafton) Elliot Smith describes fifty mummies and three hair wigs [3] and in only one case is the hair red and this probably was stained artificially.

In view of the foregoing facts, therefore, there can be no doubt that under Egyptian conditions of burial the hair certainly does not always become red even after several thousands of years, and it seems very doubtful whether it ever undergoes such a change ; in the one case where the hair is red Elliot Smith specially states that it is dyed, and suggeste henna, which is still used for this purpose in Egypt, as the dye probably employed.

[1] A. Lucas, "Ancient Egyptian Wigs," *Annales du Service des Antiquités de l'Egypte*, 30 (1930), pp. 190–6.

[2] G. Eliot Smith and F. Wood Jones, Report for 1907–8, 2, Report on the Human Remains, *The Archaeological Survey of Nubia*.

[3] G. Elliot Smith, "The Royal Mummies," *Cat. Gén. du Musée du Caire*, 1912.

CHAPTER XV

ROBBERY FROM LETTERS AND PARCELS

IT is a comparatively easy matter to open a letter or parcel fastened in the usual way or even sealed with wax and to refasten or reseal it in such a manner that it will pass muster without giving rise to suspicion unless examined critically, but it is very difficult to do so without leaving some traces of the operation, and these traces generally may be found by any one having experience, if careful search is made. When the opening and reclosing are done clumsily the evidence is very apparent, and as a rule the worse the quality of the envelope or paper the more evident are the traces left. Manifestly it would be impolitic to describe the manner in which letters and parcels may be tampered with, though the expert to whom such questions are referred naturally acquires considerable experience in these matters.

Before the expert receives a letter or parcel for investigation almost necessarily it will have already been opened by the receiver, and generally it will be found that no examination was made of it at the time of receipt, that no notice was taken of its condition, that little or no care has been taken to preserve it in the exact state in which it was received, and frequently valuable evidence has been destroyed by the careless way in which it has been handled, with the result that a handicap is imposed from the very commencement of the inquiry.

Envelopes and parcels that it is suspected or alleged have been tampered with should be photographed on receipt, since the subsequent examination frequently necessitates making some change in their appearance, such for instance as opening them in a new place or to a greater extent than was the case originally.

Method of Examination. The examination of letters and parcels from which something is alleged to have been abstracted consists very largely of a careful scrutiny (with the naked eye, with a lens and more particularly by means of the ultra-violet rays) of the envelope or wrapper and also of the wax sealings and string, if any, together with a chemical analysis of any adhesive or wax. If a package has been opened and refastened, any adhesive or wax used almost certainly will vary from that employed originally and, even if variations are not ordinarily visible, often they may be seen clearly when exposed to ultra-violet rays, different kinds of adhesives and of sealing wax frequently showing marked and characteristic differences of colour : variations also may be proved by chemical analysis.

If an envelope of which the paper has a glazed surface has been steamed

or otherwise wetted in order to open it, evidence of this generally will be found in the different and duller appearance of the paper in those places where the water has touched it, the smoothness and brilliance of the original surface having been destroyed: if the paper is not glazed, the envelope may be opened without any evidence of the operation being left unless the paper is of very poor quality, in which case even though unglazed it will show signs of having been wetted. If the edge of the flap only has been wetted, this may be proved by means of iodine solution or iodine vapour, either of which often gives a difference in colour between the wetted and unwetted portions. Any opening and reclosing of an envelope, unless done very skilfully, produces on the edges of the flap a wrinkled (cockled) appearance. Also the surface of the paper underneath the flap, either on the under portion of the flap itself or on that part of the envelope covered by the flap, is often torn. The presence of gum or wax under such tears is absolute proof that the envelope has been opened and refastened.

When gum is applied to an envelope in order to refasten it after it has been opened an excess sometimes is used that squeezes out from under the flap and can be seen readily. Such an appearance, however, although always suspicious, does not indicate necessarily that the envelope has been opened and refastened, since slight smears of gum often are found on envelopes that have not been tampered with, these being due to the fact that with a well-gummed envelope, freely moistened, a little of the original gum may be squeezed out and smeared on the envelope just beyond the edge of the flap. An envelope, too, may be regummed by the sender, either because the original gum is of poor quality or because it has disappeared, having been eaten off by beetles or other insects.

Numbers and marks placed on an envelope by the post office employees sometimes are written with copying pencil, and such marks may show signs of having been wetted if the envelope has been tampered with, and the name and address of the sender or other indications on the envelope, if made by means of a rubber stamp and aniline ink, as sometimes is the case, may show the same thing. Wetting, however, may be accidental, as for example by rain, or, in a hot country, from the perspiration of the hands of those who have handled the envelope.

In every case where tampering is suspected the envelope should be opened in such a way as to allow the inside, and particularly the inside of the flap, to be examined carefully. It should be remembered, however, that it is not always the top flap of an envelope that is tampered with, but sometimes the bottom flap or one of those at the sides. If the envelope has been opened by cutting one of the edges and afterwards has been closed again, this operation may have been performed so skilfully that no evidence will be found on a careful examination of the outside of the edge even with

a lens. To detect such a mode of opening and reclosing it is necessary to open the envelope completely by ungumming all four flaps. The best way of doing this is to hold the edges of the flaps in the steam issuing from a small glass tube attached to a vessel in which water is boiling, such as a chemist's " wash-bottle " or a small kettle, or to wet the edges of the flaps with hot water, using a small camel-hair brush, the water being " painted " on repeatedly until the gum becomes softened, when the flaps may be opened easily by means of a thin bone or ivory paper knife. On no account should the opening be forced, but patience must be exercised until the flaps open almost by themselves, which may take a considerable time in the case of a thick envelope and good quality gum.

If the envelope is sealed with wax, this must be removed before applying the hot water, which may be done by immersing the envelope in strong alcohol contained in a porcelain photographic dish and allowing it to stand overnight. If the writing or part of it is in coloured ink or copying pencil, almost certainly it will be affected by the treatment, but the danger is usually very slight and reasonably may be risked. In the morning a little gentle rubbing with the fingers will remove the wax completely. The alcoholic solution and all solid matter left in the dish should be reserved for chemical analysis. The sealings are removed in this careful manner, not merely to open the envelope, but in order to examine the condition of the paper immediately beneath to ascertain whether it is torn, as frequently is the case where the original sealings have been removed and replaced by others or where the sealings have been tampered with.

Before opening an envelope and particularly before removing the sealings it should be photographed. Also, before dissolving off the wax, care should be taken that it has yielded all the information possible, the points to be noted specially being (*a*) the colour and whether this is uniform and whether there are any signs of blackening, (*b*) the appearance under the ultra-violet rays and (*c*) whether there is evidence of more than one layer.

False wax sealings frequently may be detected on account of the metal seal used not being an exact reproduction of the original, or because the colour or the composition of the wax is not an exact match. It is possible, however, to reproduce a wax sealing in such a manner that the impression itself defies detection, but even in such a case evidence that the envelope has been tampered with frequently is left either during the removal of the original wax or during resealing. It will be found a great help in the detection of forged sealings and the opening of envelopes and parcels if the expert acquires personal experience of how to do these things. Detailed methods for the forgery of seals on documents have been published.[1] [2]

[1] S. Türkel, *Fälschungen*, 1930.
[2] H. O. Yardley, *The American Black Chamber*, pp. 50–1.

A considerable amount of valuable information may be obtained from a careful examination of the sealing wax on an envelope or parcel that has been sealed. Thus finger prints, or marks made by a fabric, or even threads from a fabric, may be found on the wax: sometimes, too, it is possible to prove that a sealing consists of two separate and distinct layers of wax, one superimposed on the other, though too great a significance should not be attached to this unless it can be proved that the wax of the respective layers is of different qualities, since occasionally it may happen that when wax is applied to an envelope it is in too small an amount or is not sufficiently hot to take the impression of the seal well and so additional wax is added. The nature and percentage of the ash also may furnish valuable information that may allow of one wax being distinguished from another of the same appearance: even small differences in colour are important, since they may indicate not only different kinds of wax, but also may show the manner in which the wax has been melted. Thus, for instance, sealing wax may be melted in the flame of a lamp or candle, or in larger quantity, in a pot by means of a burner. When melted in a flame the wax generally takes fire unless only a very small sealing is made, and when this happens, that portion which has been alight is partly burned, and particles of black carbonized material may be seen in the wax, the colour of which generally is darkened. The amount of burning and hence of carbonization, however, may be so slight that it is not noticeable, especially in small sealings. Frequently in post offices and banks, where sealing wax is required in large amount, it is melted in a small pot over a burner, which may be a spirit lamp, a gas flame, or an electric heater. When melted in this manner the wax does not inflame, and hence does not carbonize, although some colour change may and frequently does take place. The colour of a wax sealing depends therefore not only upon the colour and composition of the original wax, but also on the manner in which it has been melted. When melted in a flame the wax generally becomes darker owing to carbonization, and particles of carbonized material frequently are visible: when melted over a burner there is generally no darkening, though sometimes a change of colour, and there are no particles of carbonized matter. The amount of visible blackening, however, depends also upon whether or not the molten wax when placed on the paper was stirred with the stick of wax as is sometimes done, since in such a case the black particles may become partly or wholly masked by fresh wax and so may not be apparent. The spots and streaks of different colour sometimes seen in a wax sealing are caused generally by the existence of particles of differently coloured wax in an original poor quality stick due to imperfect mixing in manufacture.

Analysis of Sealing Wax. The following-mentioned determinations should be made, namely, (*a*) the melting point, (*b*) the amount of resins (rosin [1] and shellac), and (*c*) the amount and nature of the ash.

The melting point may be determined by floating a small piece of the wax on the surface of a little mercury contained in a wide test tube, in which is a thermometer dipping into the mercury. The tube is placed in a beaker of oil, which is heated slowly by means of a small flame, the oil being stirred continuously.

The resins may be determined by repeatedly extracting a weighed quantity of the powdered wax with hot, strong alcohol, drying and weighing the residue and determining the proportion of the extracted matter by difference.

A good qualitative test for rosin is to place a small quantity of the wax in a test tube, add a little acetic anhydride, boil, cool, pipette off a few cubic centimetres from the top of the liquid into a small porcelain dish and add one drop of strong sulphuric acid, when if rosin is present a fugitive reddish-violet colour will be produced.

To determine the ash, take a given weight of wax, but if possible not less than one gram, incinerate in a small crucible, cool and weigh the residue and make a quantitative analysis, determining especially the matter insoluble in hydrochloric acid, the sulphate, which Mitchell has found very characteristic,[2] and the nature and amount of the inorganic colouring matter present.

If the wax has been dissolved off the envelope with alcohol, the alcoholic solution should be filtered, the residue treated with hot alcohol and again filtered, then dried and weighed. The mixed alcoholic liquids should be evaporated to dryness on a water bath and the dry residue weighed, and from the weights of the matter soluble and insoluble in alcohol respectively the percentages of both may be calculated. The mineral matter (matter insoluble in alcohol) should be ignited and the ash weighed and analysed.

As already stated, wax sealings should be examined by means of the ultra-violet rays, different qualities of wax that may appear the same by ordinary light showing marked differences of colour when exposed to ultra-violet radiation. Symons has pointed out,[3] however, that various batches of the same brand of wax may vary, thus the same wax may differ slightly according to whether it has been melted recently or not or even with the manner in which it has been melted, wax that has been burned differing from wax that has been melted without burning.

[1] The residue left when the more volatile portion of the semi-liquid resinous exudation of certain coniferous trees is removed either by evaporation or by distillation.

[2] C. A. Mitchell, *Documents and their Scientific Examination*, p. 187.

[3] C. T. Symons, "The Fluorescence Test: Ultra-Violet Light in Scientific Criminal Investigation," *The Police Journal*, 3 (1930), pp. 235–43.

Analysis of Adhesive. The adhesive material that fastens the flap of the envelope should always be examined, both chemically and by means of the ultra-violet rays. This adhesive ordinarily consists either of gum arabic or of dextrin, but if an envelope has been opened and reclosed, starch paste or office paste may have been used for the refastening. The best test for starch paste is the blue colour it gives with very dilute solution of iodine in potassium iodide ; dextrin gives a brown colour with the same reagent and gum is unacted upon. Office pastes are of various compositions, but some contain alum, magnesium chloride or zinc chloride, all of which may be identified readily. Different adhesives respond differently to the ultra-violet rays and the presence of two different adhesives may sometimes be detected in this manner and Mitchell states that examination by ultra-violet rays may be of value in detecting envelopes that have been steamed open and closed again with a different adhesive.[1]

Illustrative Cases. 1. This was a robbery of a large sum in banknotes from a sealed envelope, that had been sent through the post. Part only of the notes had been taken. The following clues were found :

The wax sealings were all identical and had all been made with the same metal seal, which was the genuine seal of the firm forwarding the letter.

There were two different and distinct layers of wax on two of the sealings, one layer being subsequent in point of time to the other, and superimposed upon it.

There were wavy lines, and a few very small black-looking fibres on one of the sealings. The fibres were found on microscopic examination to be wool of a dark blue colour, and the lines to be the impression of a woven fabric.

In two places adhering to the under side of the flap of the envelope there were fragments of paper torn from the surface of the envelope beneath the flap, and these were embedded between two layers of wax, and on the envelope below the flap there were places from which the surface layer of the paper was missing, and there was wax on these torn surfaces. This could not possibly have happened unless the envelope had been sealed with wax beneath the flap (the usual method adopted by the firm forwarding the letter), then opened, the surface of the paper being torn during the process, and afterwards resealed with more wax.

All the wax was identical in colour and chemical composition, and corresponded to that used by the firm sending the letter.

The sealing wax used by the addressee, although of the same colour as the wax on the envelope, was of different chemical composition.

The post office sealing wax was also different in chemical composition from that on the envelope.

[1] C. A. Mitchell, " The Use of Invisible Rays in Criminology," *The Medico-Legal and Criminological Review*, 3 (1935), p. 9.

The dark blue woollen fibres found on the wax of one of the sealings corresponded with the material of the coat of one of the employees of the firm sending the letter, and the right-hand sleeve of the coat was turned up and frayed at the turned-up edge. There was evidence, however, that this employee might have been called in to assist in the sealing of the envelope.

It was evident from the above facts that after the envelope had been sealed in the first place it was opened at the flap and then resealed in the same manner as before, the additional wax being identical both in colour and composition to that originally employed, the impressions on the wax being made with the firm's own seal. Everything therefore pointed to the robbery having taken place before the envelope left the premises for the post, and that it was done hurriedly, since all the notes were not taken. It seems probable that after the flap of the envelope had been fastened down and when some, but not all of the wax sealings had been put on, the clerk in charge, thinking the envelope was then secure, had absented himself temporarily and that advantage had been taken of this absence to open the envelope, hurriedly abstract some of the notes and then to reseal it. Against this, however, was the fact that the postage stamps on the envelope represented the correct postage and registration fee for a package of the weight that the envelope originally had when it contained the full complement of notes, whereas when the letter reached its destination its weight was some sixty grams less, and hence it was then considerably over-stamped.[1] To meet this difficulty, however, it might be assumed that the messenger who took the letter to the post, either mechanically or intentionally, asked for stamps to represent the original weight, since it was admitted that letters of the same kind and weight had been sent to the same address on several previous occasions.

2. This case, like the last, was one of the robbery of banknotes from a sealed envelope sent through the post, the sum stolen being £E.5,000. The clues found were similar in some respects to those in the previous case, and it was possible to prove that in several instances the wax sealings were formed of two different layers of wax, one superimposed on the other. The lower and original sealings in at least some cases had been made with a rectangular seal that had been taken out of use only a few days previous to the robbery, whereas the top sealings were all made with a new circular seal. If a mistake had been made in the first instance and the wrong seal used, it would be a natural way of correcting the mistake for more wax to be added and the new seal used and, if the gum on the flap were not quite dry, the occasion might be taken to open the envelope and carry out the robbery

[1] Apparent differences in weight may be due to incorrect scales and weights, or to careless weighing: actual differences in weight occur from fragments of sealing wax being inadvertently detached, from the presence of dirt or moisture or to drying.

before resealing it. Both lots of wax were identical in composition and the seal used to make the impressions was the genuine one. In this case all the banknotes had been taken out and replaced by a packet of the same weight consisting of pieces of Arabic newspapers. The robbery had certainly been carried out by some one having access to the firm's wax and seal, and also to a balance for adjusting the weight of the newspaper packet. This had occupied some time, or careful preparation had been made beforehand for it. The papers were pieces of nine different newspapers, all published in Cairo, where the robbery took place, and the dates extended over a period of six months.

3. This again was a robbery of banknotes from a sealed envelope sent through the post, the amount stolen being £E.3,000. In this case, as in the one last mentioned, all the notes were abstracted and pieces of newspaper substituted. The following significant facts were noted:

Of the nine wax sealings on the envelope five were on the flap and four elsewhere. The wax of the latter was identical both in colour and in composition with the firm's wax, and the seal used was identical with the firm's seal, and these four seals were undoubtedly part of the original sealing. The colour of the wax of the five sealings on the flap was slightly but definitely different and darker than that of the other sealings though the composition was the same: small differences in detail proved that the metal seal used to make these impressions was different from that used for the other four impressions, and that it was not the firm's seal.

The post office sealing wax was different both in colour and in composition from any on the envelope.

A portion of the surface layer of the paper of the envelope beneath the flap was torn away and was adhering to the flap, and in several places small pieces of paper were found between two layers of wax, all of which proved that the envelope had been opened and resealed after it was originally fastened.

The newspapers, with one exception, were all published in Alexandria, the place from which the envelope was sent: the exception was a Cairo paper having an extensive circulation in Alexandria. One of the Alexandria papers was dated the same day that the envelope was posted.

The conclusion was that the robbery took place in Alexandria, and not at the post office, and that unless the firm had other wax different from that of the four sealings and from that of a specimen submitted for examination, which point was not cleared up satisfactorily, the robbery did not take place on the firm's premises, since in such a case it would have been a very easy matter to have obtained some of the firm's wax; hence by exclusion the robbery occurred while the envelope was in transit between the firm's premises and the post office.

4. Two similar envelopes were sent by post by the same person from the same place on the same day to the same address. Each was stated to contain banknotes, one for £E.400 and the other for £E.320.. On arrival the £E.320 was intact, while the other envelope contained pieces of thick pink paper instead of banknotes. This paper consisted of wrappers from packets of a well known local cigarette tobacco. Both envelopes were sealed in the same way with five wax sealings, all of which were identical and had been made with the same metal seal. There were no signs that the envelope from which the banknotes were missing had been opened and resealed, nor that it had been tampered with in any way. The envelopes were of the kind sold only at the post office, and it was proved that they had been purchased several days before the robbery : the writing was that of the local postmaster, who admitted that in contravention of regulations he had addressed and sealed the letters, using the post office wax and the seal of the sender ; he stated, however, that the envelopes were gummed down already when they were handed to him. As a result of the inquiry it was proved that the owner of the money had robbed himself and had arranged matters in such a manner as to throw suspicion on the postmaster.

5. A key had been abstracted from a sealed envelope, used for the purpose of robbery and then replaced in an envelope similar to the first, but this was done very clumsily and it was proved readily that the envelope and sealing were not the originals.

6. In several cases there have been no signs that envelopes from which it was alleged that money or papers had been stolen in transit had been tampered with. In one instance there was no extra gum ; six seal impressions across the flap made with blue aniline ink had not been wetted, and the two parts of these seal impressions (the one on the flap and the other on the envelope) corresponded exactly ; two pieces of stamp edging placed across the flap also showed no evidence of having been removed and replaced, and there was no evidence of the envelope having been opened in any other way. It seemed probable that the money had never been placed in the envelope. In another instance an envelope sent through the post was found on arrival to contain a blank sheet of paper instead of banknotes for £E.13. The evidence indicated that the envelope had not been tampered with and hence that the money had never been forwarded. One unusual feature was that the flap of the envelope had been gummed twice, but this second gumming was not the work of an amateur, but had been done during manufacture, and when search was made other instances of the same mistake were found. In a third case an important document was missing from an envelope that had been delivered by the post in the usual way. On examination it was found that although the flap of the envelope had been sealed with wax it had not been gummed down, and it seemed

probable either that the letter had been abstracted before the envelope had been sealed, or that it had not been put in the envelope. There was no evidence to show that the envelope had been tampered with. Other cases have been without any particular interest and need not be mentioned.

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CHAPTER XVI

TOBACCO

THE chemico-legal expert occasionally may be called upon to identify a specimen of tobacco found in connexion with a crime. Any tobacco so found will almost certainly be in the form of the unsmoked end of a cigar or cigarette. Thus, in the case of the attempt on the life of H.H. the late Sultan Hussein of Egypt in 1915, several cigarette ends, one being still alight, were found on the floor of the room from which the bomb was thrown, and it seemed probable that this latter had been used to light the fuse of the bomb. These cigarette ends bore the name of a certain tobacconist, and cigarettes bearing the same name and mark were found in the house of one of the accused persons. The tobacconist stated that he supplied the accused with a special mixture. In view of these facts it became important to ascertain whether the tobacco in the cigarette ends and that in the cigarettes of the accused was identical, and whether it was the particular mixture in question.

The chief differences between various tobaccos are the size, shape, colour and general appearance of the leaf, and more particularly the flavour on smoking. When a tobacco is cut, the size, shape and appearance of the leaf are lost, and in the case of a cigar or cigarette that has been partly smoked, the colour of the tobacco may be modified by the moisture and products of combustion which accumulate in the unsmoked end, and the best test, namely the flavour, cannot as a rule be applied, since even if the amount of tobacco available were sufficient, such a test would destroy the evidence. For the same reason a chemical analysis is also precluded, since as a rule a single small specimen of the tobacco is all that is available. One is forced back therefore upon such facts as the appearance of the tobacco, both to the naked eye and when examined under a lens or with a microscope. In the case referred to the tobacco was particularly finely cut, and this fact together with the proportion and size of the cross sections of stem present made it very characteristic and quite different from a number of other cigarette tobaccos examined, and since the tobacco of the cigarette ends and that of the cigarettes belonging to the accused had the same characteristics as well as the same general appearance and colour, it was probable that they were the same tobacco.

Whenever there is a sufficiently large sample of tobacco a chemical analysis should be made. The determinations likely to be most helpful are the amount and nature of the ash. The following table shows

some of the constituents of the ash in which the most marked differences occur [1].

TOBACCO ASH

Kind of Tobacco (*a*).	Total Ash.	Potassium Chloride.	Lime.	Magnesia.	Potash.	Sand.
	%	% (*b*).	% (*b*).	% (*b*).	% (*b*).	% (*b*).
China . .	14·8	3·7	31·1	12·7	14·4	2·1
German . .	25·9	25·0	35·7	6·5	—	0·9
Havana . .	21·4	12·7	33·1	5·3	11·8	1·8
Java . . .	18·8	19·6	22·3	8·5	14·1	1·7
Kentucky . .	18·0	2·4	29·5	6·8	16·8	5·3
Latakia . .	18·2	4·1	34·7	5·5	19·6	0·9
Manila . .	21·4	6·5	33·3	7·2	16·3	0·6
Turkey . .	12·9	19·3	22·5	9·2	14·5	1·8
Virginia ripe .	15·0	2·5	18·9	6·7	34·2	1·0
Virginia bright .	12·3	7·0	21·7	12·4	22·2	1·3

(*a*) The tobacco was dried at 100° C. before being analysed.
(*b*) Calculated on the ash.

When dealing with cigarettes, if the size of the sample will allow, the tobacco and paper should be examined separately, the former for the nature of the tobacco, of which one important feature is the amount and composition of the ash, and the latter for the nature both of the fibre and of the sizing material.

It has been stated that since the ash of different tobaccos varies considerably in composition (as may be seen from the figures given) therefore from an analysis of ordinary tobacco ash, such as might be found on the scene of a crime, the nature of the tobacco smoked by the criminal may be ascertained. Such an argument, however, neglects to take into consideration one most important factor, namely that tobaccos as sold are always mixed; thus both pipe and cigarette tobaccos are invariably blends and even cigars are not made from a single kind of tobacco, the outside leaf or "outer wrapper" being different from the rest of the cigar. Also there is no certainty that the same blends are always employed for the same brands of tobacco or that they are employed in the same proportion. Cigarette ash too necessarily includes the ash of the paper.

In order to determine if possible the value of tobacco ash as a clue in criminal investigation, I made analyses of (*a*) the ash of several different brands of cigars, (*b*) the ash of fourteen kinds of cigarettes, each specially made from a pure unmixed tobacco, and (*c*) the ash of several different brands of cigarettes as found on the market. The analyses were only partial, the determinations being confined to the constituents that appeared likely to be the most useful for differentiating the various tobaccos. The results obtained appear on page 330.

[1] Sir Ed. Thorpe, *A Dictionary of Applied Chemistry*, 7, 1927, p. 82.

CIGAR ASH

Kind of Cigar.	Colour of Ash.	Chlorine as Potassium Chloride.	Matter Insoluble in Hydrochloric Acid (Sand).
		% [1]	% [1]
Havana	light grey	12·2	14·5
Indian A	dark grey	25·0	13·8
Indian B	dark grey	24·0	12·1
Indian C	dark grey	22·3	18·4

[1] Calculated on the ash.

CIGARETTE ASH

Kind of Tobacco.	Total Ash.	Chlorine as Potassium Chloride.
	%	% [1]
Algerian	17·3	27·5
American	15·6	2·0
Bulgarian	18·5	1·6
Burmese	19·0	0·7
Chinese	10·0	2·5
Greek	19·2	10·3
Indian	15·8	42·3
Japanese	18·0	3·1
Porto Rico	16·1	23·9
Russian	22·3	3 4
Serbian	17·3	1·7
Turkish (Samsoun)	14·5	5·0
Turkish (Smyrna)	19·7	5·5
Turkish (Cavalla)	15·2	2·8

[1] Calculated on the ash.

CIGARETTE ASH

Kind of Cigarette.	Chlorine as Potassium Chloride.	Matter Insoluble in Hydrochloric Acid (Sand).
	% [1]	% [1]
English	3·6	36·0
Egyptian A	7·5	20·6
Egyptian B	7·4	18·1

[1] Calculated on the ash.

These results show that considerable differences occur in the proportion of chloride present in the ash of various tobaccos. Thus with respect to the particular cigars and cigarettes examined there was approximately twice as much chloride in the Indian cigars as in the Havana cigar and twice as much chloride in the Egyptian cigarettes as in the English cigarettes. Both from the colour of the ash and from the proportion of chloride present there was therefore not any difficulty in distinguishing between the ash of the Havana cigar and that of the Indian cigars. In the same way the ash of the English cigarettes could be distinguished readily from that of the

Egyptian cigarettes. The matter insoluble in hydrochloric acid did not show a sufficiently large difference in amount in the various kinds of cigars to be helpful, but in the case of the cigarettes the English ones contained approximately twice as much as the Egyptian ones. This insoluble matter, which was examined microscopically, consisted largely of silica, the only marked difference being that in the Havana cigar ash it was in a finer state of division than that of either the Indian cigars or the cigarettes. The differences in the proportion and nature of other minerals besides the silica were very small and not enough to be characteristic. The experiments, however, have been too few to enable any general rule or hard and fast limits to be laid down, but manifestly from the appearance and chemical analysis of tobacco ash the nature of the tobacco smoked sometimes may be proved. The principal value of such evidence will probably consist in the negative fact that a certain suspected person does not smoke the particular kind of tobacco indicated by the ash found, and hence that he may be eliminated from the case. The positive fact that a certain person does smoke the kind of tobacco shown by the ash found may mean very little, since no matter what the tobacco may be it will certainly be smoked by a great number of people other than the criminal.

Method of Analysis. *Ash.* A weighed quantity of tobacco is slowly incinerated by means of a Bunsen burner in a small platinum or porcelain dish, the heat employed being the lowest possible to ensure complete combustion of the carbon and not sufficiently high to result in fusion, the end of the operation being indicated by the white or lignt grey colour of the ash. A muffle furnace should never be used. The contents of the dish should be stirred with a stiff platinum wire from time to time during the ignition, the wire being weighed with the dish.

Chloride. A weighed portion of the ash is transferred to a small standard stoppered flask, distilled water added to the mark, the flask well and repeatedly shaken, the solution filtered and an aliquot portion taken and titrated with standard silver nitrate solution in the usual way. The result is calculated to chlorine or potassium chloride.

Sand. A weighed portion of the ash is boiled with hydrochloric acid, the solution filtered and the residue washed, dried, weighed and examined. A microscopical examination both with and without polarized light should be made.

Illustrative Cases. Cowap reports a case in which cigarette ash found upon the clothing of a dead woman was proved not to have been derived from her own cigarettes, but was indistinguishable from the ash of the cigarettes smoked by a suspected person.[1]

[1] J. C. Cowap, *Annual Report of the Gov. Analyst, Straits Settlements, for the Year 1934*; *Analyst*, 60 (1935), p. 473.

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