Criminalistics

A new and independent discipline evolves from modern techniques and new concepts of individualization.

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The clothing of a burglary suspect is brought to the laboratory. In the burglary being investigated, glass was broken. Glass fragments removed from the clothing are routinely compared with broken glass from the scene of the crime by means of the density-gradient method. The clothing is found to contain glass from four different sources, none of them from the scene of the crime. The suspect is probably a burglar, but he had no part in this particular crime. An old man is struck and killed by a hit-run automobile driver. Paint chips caught in his clothing identify the vehicle as probably a 1959 Dodge of a particular color. The type of damage to the automobile is deduced from a study of the types of bodily injury, the location of the paint on the victim's clothing, and the known behavior of human bodies struck by vehicles. A 1959 Dodge of the correct color and with corresponding damage is located, and another crime is solved. A dope peddler is identified by tiny fragments of marihuana leaves, or by traces of heroin, in his pockets.

Happenings such as these constitute the daily routine of a criminalistics laboratory, which quietly provides factual information to the authorities and assists in determining the guilt or innocence of thousands of suspects every year. Criminalistics is an occupation that is poorly understood by the great majority of people, including the scientific public. It is generally assessed in terms of high-grade detective work rather than in terms of a serious and very demanding type of applied science. Its evolution from the natural sciences and its current trends, its limitations, and its future possibilities are the subject of this discussion.

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Shift of Orientation in the History of Science

In the realm of the natural sciences, the history of the development of human thinking is a complex and fascinating study. The ancients were concerned with natural philosophy, from which modern science evolved, and they made extensive and accurate observations. However, their thinking was on the intellectual plane; they did not experiment. With the early experimental approach of Archimedes, Copernicus, Galileo, Leuwenhoek, Newton, and Lavoisier, to mention only a few, fundamental disciplines that we now recognize as individual sciences developed. The monumental achievements of these men became the foundations of structures that their originators could not have predicted or even comprehended. Indeed, we still cannot forsee their ultimate evolution.

In more modern times, a different type of discipline emerged, one based on the practical needs of humanity rather than upon mere curiosity about nature, important and productive as that was. From this newer trend developed, among others, the disciplines of medicine, engineering, and law. For such disciplines the term *profession* was more suitable than *science,* for some of them made no direct use of science as currently defined, and others synthesized many scientific principles and facts into a heterogeneous whole of which the central core was a human need. In the latter category, medicine is the best example. It adopted knowledge from every science that bears on the physical nature of man, his abnormalities, and his diseases in order to minister to his health. Similarly, engineering adopted those principles and data that were of use to it in constructing the man-made world. In these and other disciplines the significant alteration in thought was related to human activity rather than to the broader and more objective concerns of pure scientific development. Nevertheless, some of these disciplines did develop specific new sciences within themselves.

As scientific knowledge in any broad category has been extended past the stage of easy comprehension, it has been divided and subdivided into specialties which can be mastered by the individual. The process is now being reversed in many of the more complex enterprises of modern man. Physicists and engineers must not shoot men into space without extensive and thorough consideration of man's physiology under stress, his psychology, and his basic biological needs. Atomic energy was not born without great preoccupation with mineralogy, metallurgy, ceramics, microchemistry, and medical science, as well as with the physics and chemistry that were basic to solution of the primary problems.

A New Discipline To Meet an Old Need

Crime is just such a complex problem. It is perhaps the oldest problem that confronts mankind, and the one that has received the least attention from scientists and other thinkers. Quantitatively, the problem of crime is far greater than many of the problems on which untold millions have been spent—for example, spectacular diseases such as cancer or poliomyelitis. According to reliable statistics, one person out of every 68 to 70 will be the victim of a felony each year. Thus, at man's present life expectancy, every citizen is likely to be the victim of a major criminal act in the course of his lifetime. As compared with cancer or any other specific disease, crime gives us very poor odds indeed.

Furthermore, the economic aspects of crime are generally not appreciated, partly because reliable figures are not available. A study made some 20 years ago gave an estimate for the total cost of crime in the United States as $20 billion a year. This figure included a large item for organized crime, but it seems reasonably certain that inflation, increase in population, and a general increase in the crime rate have augmented the cost significantly, whether or not organized crime is included.

Reliable or not, the statistics indicate the magnitude of the problem and justify the conclusion that more is needed to deal with it than the almost random and inexpert methods that are the norm.

Criminalistics is one of a very few activities based on natural science that have arisen in response to this need. It is concerned with the study of physical objects and physical facts relevant to the crime, from which a reconstruction and understanding of the crime may be developed. It helps to establish the facts and to determine the guilt or innocence of an accused person, although the latter is not its primary function. Criminalistics has not been extended into areas currently based on sociological and psychological concepts, which also are in an early stage of investigation. That it may intrude into these areas in the future is not unlikely. Because evidence is of every imaginable kind, criminalistics, like medicine, has borrowed from all science that which is applicable to its needs. Also like medicine, it has developed a limited science of its own, made necessary by its special requirements.

The Realm of the Unlikely

Criminalistics is concerned with the unlikely and the unusual. Other sciences are concerned primarily with the likely and the usual. The derivation of equations, formulas, and generalizations summarizing the normal behavior of any system in the universe is a major goal of the established sciences. It is not normal to be murdered, and most persons never experience this unlikely event. Yet, when a murder occurs, some combination of circumstances suddenly alters the situation from unlikely to certain. What happens here has never been mathematically analyzed, although the need for such an analysis has long been apparent. Mathematical analysis is even more necessary for interpreting the significance of each fact that is elicited relative to the evidence. However, we do not yet know how to make such an analysis, despite technical success in determining the actual facts of a crime through study of physical evidence. The lack of mathematical exactness in the interpretation of the facts, and its effect upon an accused person, is sometimes tragic. Despite the so-called safeguards of the law, it is not possible to prevent the release of many guilty persons or the conviction of a few innocent men. Until this area of science also is reduced to reasonable mathematical exactness, the administration of justice will be correspondingly hampered.

For example, in one murder case, misuse of statistical reasoning produced the argument that the chances that a particular gun was the murder weapon were several hundred to one, because it was a revolver rather than a pistol, it had six lands and grooves and a right-hand twist, and it was of a particular caliber. The interdependence of several of the variables was disregarded, as was the fact that firearms with these exact class characteristics could be very plentiful. In the absence of actual identification of the weapon as having fired the fatal bullet, such an argument could lead to unjust conviction.

Too much cannot now be expected of criminalistics as an exact science. Too many criminalists are still being trained by working in a crime laboratory under more experienced but sometimes unscientific persons. This is analogous to the early days of medicine and law, when the future doctor was apprenticed to the practitioner and the embryo lawyer "read law" in a law office. All professions have abandoned this hit-or-miss method of training. Although criminalistics is a discipline, it is not yet a mature enough discipline to have emerged from the apprenticeship system. The universities, the public, and even the law-enforcement agencies have been slow to recognize that systematic, thorough, and complete training must be made available to individuals on whose knowledge the liberty and even the lives of other persons may later depend. This is a responsibility second to none. The responsibility is made even heavier by the fact that the criminalist cannot hide his errors by attributing them to acts of God or to unavoidable circumstances. His testimony is a public record under the spotlight of publicity. His performance needs to be perfect, for it cannot be repeated or amended.

Principles, Techniques, Instrumentation, Objectivity

What characteristics warrant the recognition of criminalistics as an independent discipline? As with the other disciplines, there is a thread of principles that bind the parts into a coherent whole. These principles center on identification and individualization of persons and of physical objects. Determination of the nature of an object and of its specific origin is basic in interpreting a crime or an accident. In addition, there must be standards of performance, training, and ethics. In California all of these requirements have been met through the efforts of the California Association of Criminalists (*1*) and of several colleges and universities of the state; in some other jurisdictional areas limited progress has been made.

Along with principles must go techniques. These are applied not at random but rather to the degree to which they lead to reliable identification and reveal the individual origin of the item identified. While the variety of instruments and of techniques is very great, each is useful only in the limited context of its direct contribution to the individualization of the object of evidence. It is in the area of new techniques and instruments that criminalistics is now making its greatest strides, even before there is a reliable basis for exact interpretation of the results. For instance, it is possible to identify all types of textile fiber with exactness, through a variety of methods that include microscopy, chemical testing, x-ray diffraction, and pyrolysis-gas chromatography. However, the probabilistic value of a fiber transfer between two sets of clothing, as in a crime, is still a matter of controversy, even though such transfers constitute one of the more valuable types of evidence.

Just as the skill of the doctor does not rest on the excellence of his stethoscope or the sharpness of his scalpel, the excellence of the criminalist does not depend on the multiplicity of his instruments. A master of all techniques may remain merely a technician, and the best of all technicians is not necessarily a satisfactory criminalist. The criminalist must analyze the problem and understand the principle in order to arrive at a correct interpretation of the criminal act. In addition, he must be second to none in objectivity, for on his objectivity may depend the lives and liberties of other people. These obvious facts bear repeating only because they are often disregarded.

According to an old axiom, nature never reproduces herself exactly; thus no two objects in the universe are ever totally indistinguishable. However, two pieces of the same original object share many properties and are so much alike that, if one piece is of known origin, the origin of the other can be established.

The properties that may be used for establishing the source of a sample are of three types—morphological, compositional, and spatial. Since two objects cannot occupy exactly the same space at the same time, the spatial property of an object is of ultimate value, but only in those infrequent cases where it is applicable. Thus, for most identification problems, only morphological and compositional properties are useful. Until recently, morphological properties were, by a very large factor, the most valuable, because they are often a means of definitely establishing the origin of a sample. For example, a broken piece of glass may show an exact fit with the fracture surface of another piece of glass. This type of morphological agreement constitutes the most exact means of establishing a common source. Compositional comparisons have not ordinarily been able to provide such clear proof of common origin.

Morphological evidence is generally "pattern" evidence. Evidence of the broken-glass type depends upon pattern, as do fingerprint, bullet striation, and many other common classes of evidence. Compositional factors may also yield a pattern—for example, an absorption curve or the tracings from a recorder attached to an x-ray diffraction apparatus, a gas chromatograph, or any one of a number of other instruments. Pattern evidence has been considered the most reliable indicator of the identity or nonidentity of origin of two samples. Now it appears that evidence of even greater value can be obtained from the detailed evaluation of compositional impurities by means of neutron activation analysis.

It is apparent that, in the criminalistic sense, two samples having exactly the same absolute composition could never be distinguished except through morphological or spatial comparison; nor, theoretically, could two samples of an absolutely pure compound be distinguished. (Actually, no pure compound exists or has ever existed.) Two samples from different sources would never be expected to have the same absolute composition. With respect to any given sample, chemical analysis is concerned with only a few elements, despite the fact that any sample on earth, however small, may be expected to contain some quantity of any, or even all, of the elements on earth.

Identification and Individualization

The development of neutron activation analysis has provided a new and highly significant approach to the solution of the problem of individualization. By chemical methods many elements cannot be detected in dilutions greater than 1 part per million, and few, if any, are detectable chemically in concentrations of less than 1 part per billion. Yet 1 gram of a material could contain an impurity of atomic weight 100 at the level of 1 part per billion to the extent of about 10^{12} atoms. It is evident that there is ample opportunity for chemically nondetectable contamination of any sample by any and every element. This seeming obstacle becomes an advantage under neutron activation analysis, by which some elements can be detected, identified, and (in favorable instances) determined quantitatively in quantities in the picogram range (10^{-12} g). This constitutes a major breakthrough. In this process the sample is subjected to a high flux of thermal neutrons (or sometimes high-speed neutrons) and the radioactive isotopes of both the major and the minor constituents are formed. Neutrons may be generated by more than one method, but the highest flux has been obtained in the nuclear reactor, which is becoming increasingly available for this use. The resulting active mixture can be subjected to direct gamma-ray spectrometry for immediate analysis, or the products can be separated chemically and evaluated quantitatively by means of a simpler counting device for gamma or occasionally beta rays. If it can be used, gamma-ray spectrometry is preferable for two reasons: (i) it is a rapid, nondestructive method of analysis, and (ii), because it *is* rapid, the short-lived isotopes can be measured. In destructive chemical operations, no matter how rapidly they are carried out, some of the short-lived isotopes inevitably decay past the point of evaluation. The major advantages of chemical separation are that mutual interference of isotopes of very similar energies is eliminated and that beta rays as well as gamma rays can be counted.

Already, major advances have been made in individualization studies of a wide variety of evidential materials through neutron activation analysis, and work is progressing rapidly at several sites where facilities are available. Perhaps the most notable advance is apparent in the work on human hair. As early as 1961 a group of Canadian researchers (*2*) reported the detection in human hair of measurable amounts of gold, cobalt, manganese, molybdenum, selenium, chlorine, bromine, iodine, mercury, germanium, and chromium, in addition to the arsenic, copper, zinc, iron, silicon, sodium, and vanadium which had been recognized earlier (*3*). Not all of the newly reported elements appear in all hair samples, and the concentrations differ for different people. In a study of hair samples from 30 persons, no two samples from different individuals showed similar patterns of trace-element content, while in replicate determinations for different samples from the same person, the results were reproducible to within the precision of the individual determinations. Thus, with a limited number of samples it was shown that the individuality of human hair is demonstrable through quantitative determination of the components. Study of one individual's hair over a period of a year showed some slight changes in composition, especially with respect to selenium, copper, and gold. However, the general pattern was clearly recognizable over that period. Samples from a single individual taken 14 years apart showed appreciable variation, as would be expected with the changes that occur in environmental factors and diet. General confirmation and considerable extension of this work have been accomplished by a group at Oak Ridge National Laboratory (*4*).

Similar studies of tissues, blood, dust, soil, cloth fibers, and numerous other materials have been, or are being, made by the Oak Ridge group and by other groups of researchers. An unusual application of neutron activation analysis is its use in determining whether or not a particular person has fired a gun (*5*). Although the dermal nitrate test has been employed widely for many years, it is known to be unreliable, and recommendations against its use have been made by the California Association of Criminalists and possibly by other organizations. With the neutron activation method, a finding of antimony, barium, and copper (gunshot residues) in swabbings of the hands appears to be a reliable indication that the individual has fired a gun. This would be the first reliable indicator we have had. Furthermore, the data obtained also indicate the type of ammunition used and the number of shots fired. It is safe to predict that activation analysis will soon make it possible to solve a large number of criminalistic problems of types that have hitherto seemed baffling.

Neutron activation analysis, spectacular as it is in the area of criminalistics, is not the only new development in this field. Infrared absorptiometry, very familiar to the chemist, is now being used extensively in the crime laboratory for individualizing organic materials because it furnishes a complex pattern with many points of comparison. Highly sophisticated techniques such as nuclear magnetic resonance and electron spin resonance are being used occasionally on an experimental basis.

Gas-liquid chromatography is another technique now being used to solve some of the more difficult problems of the crime laboratory. A relatively new technique in criminalistics, though for years a tool of the petroleum chemist, this method is now used for identifying and separating many drugs and poisons that were formerly thought to be insufficiently volatile to be separable in the vapor phase. Pyrolysis in combination with gas-liquid chromatography promises to be a simple and very powerful method for identifying samples of organic materials of all types (*6*). The usefulness of gas-liquid chromatography in the investigation of fires and explosions and of industrial accidents involving volatile organic materials is obvious.

Techniques of the biologist are also being used extensively in criminalistics. For example, it now appears that through immunoelectrophoresis, largely a biochemical and medical tool, we will soon take a long stride toward determining the individuality of blood (see *7*).

The forensic sciences, and especially criminalistics, are the sole point of contact betwen science and the administration of justice. Although science, in the form of medical, chemical, criminalistic, and engineering service to the courts, has been of enormous value, its full potential in this role is yet to be realized. Not only are scientists unacquainted with the law and its operation but they are often reluctant to be involved in legal matters. Law enforcement personnel and attorneys are less reluctant to utilize the techniques of science, but often they are ignorant of the services that are available to them and of how to engage them. The result is slow progress in establishing the necessary understanding and liaison.

Probable Future Trends

The recent exceedingly rapid development of science in general has not extended to forensic science. Signs abound that the ultimate role of criminalistics will be far broader and more significant than merely the study and interpretation of evidence. To illustrate, there is now strong evidence that certain mental diseases, notably schizophrenia, are associated with abnormal blood components (*8*). It also is recognized that alcoholics and drug addicts have metabolic abnormalities. Conditions such as these are certainly related to criminality, and it may well be that detectable physiological or other abnormalities may also be characteristic of certain forms of criminality. Questions of "legal insanity," or of the distinction between illness and crime in the case of addicts and others, should be decided on the basis of improved laboratory methods rather than the inconclusive and controversial methods now available. The vast areas of electronics, of computers, of psychopharmacology, and of other active fields of scientific research have had little impact upon the administration of justice. When more widespread understanding and interest are accorded forensic science—criminalistics in particular—a complete revolution in our methods of combatting crime, the oldest problem of society, may be confidently expected.

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