victim. In most crimes, the perpetrator will take items of monetary value, like cash or jewelry. They may also take evidence, such as a weapon. The serial killer often takes something known as a trophy or souvenir, of no obvious value except to him in his fantasy world. The item is known as a trophy if it is seen as a symbol of achievement and a souvenir if it is to remind the killer of the crime.

Trophies and souvenirs are an important part of the killer’s modus operandi (“method of operation,” or M.O.), the name given to the particular tools and strategies that distinguish the killer’s work. The M.O. includes factors such as the location of the crimes, the tools used, the time of day, the alibi, and any accomplices involved. The M.O. may, of course, evolve over time as the killer becomes more experienced. The investigators will be particularly interested in any details that are unique to that killer, such as leaving a note behind. They will also look for the signature of the crime. Trophies and souvenirs can be part of the signature, as can mutilating or having sex with the corpse, or placing the body in a certain position.

Victimology, the study of the victim, can be crucial in tracking down a serial killer. The investigators need to know what it was about that particular person that attracted the killer. Was the victim truly chosen at random or had the person been stalked previously? The killer may have been searching for the one person who fit his fantasy and, if a common link can be found between the victims, this may be very revealing. For instance, nearly all of the victims of serial killer Ted Bundy had dark hair parted in the center.

The location of the serial killer’s crimes is also of significance. Geographical profiling is based on the premise that the killer will operate in a zone where he feels comfortable. This may be near home or, alternatively, far away from it, depending on his psychological make-up. Location is not just where the crime was committed, but is also where the victim was abducted and where the body was taken and left after the crime. Establishing a geographical profile can be challenging if the victim was a prostitute, for instance, or someone who might not be missed by relatives or co-workers for a while. The Yorkshire Ripper killed several prostitutes in the United Kingdom from 1977 to 1981, and the difficulty of tracking the victims’ movements sometimes hindered the investigation. Sometimes bodies are dumped in remote places and may not be found for some time. In such cases, a forensic anthropologist may be called in to judge the times of death so the order in which victims were killed can be determined.

The world’s most prolific serial killer was Dr. Harold Shipman, a British physician who took his own life in prison in 2004. He may have been responsible for up to 300 deaths, but the true figure will never be known as he always denied the killings. Prior to this, the so-called “Monster of the Andes,” Pedro Lopez, held this dubious distinction, having been convicted of 57 murders in 1980. He may have killed many more; his victims were young girls in Colombia.

Despite his notoriety, Shipman was, in many ways, an unusual type of serial killer. His victims, many of whom were elderly women, met their end through morphine injections, one of the main methods of assisted suicide, which some believe to be a compassionate act. He was well known and liked in his community, and there was no obvious motive for the crimes. Some psychiatrists have suggested Shipman disliked older women, or that he was trying to re-enact the death of his mother. Others believed he gained pleasure from the power of life and death that he could exercise as a doctor. Shipman may have begun to kill patients very early on in his medical career, before he had even finished training to be a doctor. Initially, it was thought he began his career as a serial killer in 1974 when he first became a family doctor. This would put the number of deaths between 216 and 260. If, however, he began to kill almost as soon as he had the opportunity, then at least 24 more deaths, and maybe more, could have been at the hands of Shipman.

SEE ALSO Bundy (serial murderer) case; Psychological profile; Psychopathic personality.

Serology

Serology testing (assay) is largely used by forensic laboratories to analyze blood samples from suspects and bloodstains collected at the crime scene, in order to identify blood types of victims and assailants. The main objective of forensic tests, whether serological or other types, is to individualize samples through the identification of their sources.

Blood is the most common physical evidence in accidents, murder cases, and violent crime investigations. Besides blood, crime scene technicians may also find other stains and residues similar to blood in appearance at the scene, such as tomato sauce, red paint, or animal blood. To identify human blood, forensic scientists test samples at the crime scene with the chemical phenolphthalein, in an assay known as...
the Kastle-Meyer color test. Phenolphthalein releases hydrogen peroxide that reacts with an enzyme known as catalase in the blood. Catalase breaks down the hydrogen peroxide into water and oxygen, therefore releasing bubbles. However, as vegetables, animals, and some bacteria also produce catalase, this test only rules out the inorganic samples. Organic (plant or animal derived) samples are then collected for further serological analysis at the crime laboratory.

Body fluids such as blood, semen, saliva, and sweat, all contain serum. Serum is a liquid component of blood composed of water, trace minerals, several proteins including albumin, and immunoglobulins or antibodies. Albumin is the sticky protein that gives blood enough density for the water within it to remain inside the walls of arteries and veins. (Egg white contains high levels of albumin, which gives it the characteristic consistency.) When red and white blood cells are removed from blood, the resulting clear golden yellowish liquid is serum. Serology is therefore the study of the properties of serum. Serological tests have a wide range of applications in medicine, such as immunology and allergy assays, infection diagnosis, and blood typing. Serology can determine whether an individual was exposed in the past or if he is presently infected with a variety of pathogens (disease-causing organisms), such as hepatitis, measles, anthrax, syphilis, or HIV. Serology tests can also determine the presence of alcohol, illegal drugs, and poisons in the serum. Serological tests are also used in forensics to identify blood ABO groups, whose results, although not conclusive, may help to exclude or include suspects in the investigation process. If for instance, a suspect is blood type B and the samples from the crime scene are all types A and O, the suspect with type B blood can be excluded from the investigation.

Serology is such a convenient diagnostic tool because the immune system produces specific molecular tags in the blood for practically each foreign substance or invading microorganism. Each one specializes in binding to a specific molecule such as a viral, parasite, or bacterial protein, as well as to foreign substances such as poisons and drugs. For minutely small drug molecules against which the immune system is not very sensitive, special immune reagents were developed for the detection of drug abuse. An example is the Homogeneous Enzyme Immunoassays (EMIT), which is commercialized in kits ready for use.

To determine whether a blood sample is from a human or animal source, samples are tested with anti-human serum. This method was discovered by the German biologist Paul Uhlenhunth in the late 1870s. He injected protein from a chicken egg into a sample of rabbit’s blood. After a few days, he extracted the rabbit’s serum and mixed it with egg white, causing the separation of egg proteins from the solution to form a whitish clotting substance, precipitin. Precipitin is now a generic name for the resulting agglutinated complex formed when antibodies present in the serum of a species agglutinate the proteins in the blood of a different species. The forensic test consists of collecting the blood sample in a test tube containing serum from a rabbit containing antibodies against human blood, known as anti-human antibodies. If an insoluble complex of precipitin (clumping) occurs, the test is positive for human blood. This test can also be conducted using gel-electrophoresis, when a blood sample is put on a glass slide and covered by a layer of agar gel. The slide is positioned side by side with another containing the rabbit anti-human serum, inside a box filled with a solution that conducts electric current. As the current passes through, protein molecules are filtered into the gel and toward each glass slide. If precipitin is formed, the test is positive, and the blood sample is identified as human blood.

Electrophoresis is also used in typing the different groups of human blood, known as the ABO grouping system. After the discovery of antibodies and antigens (molecules to which antibodies bind), scientists identified four blood types among humans between 1875 and 1901. All human blood contains antigens in red cells that vary in type among individuals in accordance with inheritance (e.g., maternal and paternal inherited genes). Genes A and B (chromosome 9) encode enzymes that add specific sugars to an antigen at the ends of a complex sugar molecule (polysaccharide) that is present on the surface of erythrocytes (red blood cells). Individuals who inherit neither A or B genes have type O blood. As genes A and B are codominant (they do not dominate each other), individuals who inherit both genes (one from each parent) are type AB. The following other inherited combinations may occur: AA, BB, AO, BO, OO. Individuals AO or BO are respectively heterozygous type A and type B. AA or BB are homozygous types A or B.

Blood typing tests consist of mixing blood samples with anti-serum A on one side of the slide, and with anti-serum B at the other side. If the agglutination (clumping) occurs on both sides of the glass slide, the blood is AB. If it occurs only with anti-serum A, the blood is type A, or if it occurs only with anti-serum B, the blood is type B. If no agglutination occurs, the blood is type O. Because a person with type O blood does not present antigens to either A or
B antibodies, they can donate blood to most blood groups. Carriers of gene A that have antibodies against B antigens in their blood plasma, and vice versa, can only receive transfusions of the same blood type or from type O blood. Individuals with AB blood type can receive transfusions from all donors. Type O carriers however cannot receive blood from the other types because their plasma contains antibodies against A and B antigens.

Population prevalence of blood types is approximately as follows: type A is more common in Caucasians and Europeans; type B among Africans, African descendents, and South Asia populations; AB type is predominant in China, Japan, and Korea; and Type O is predominant in Native Americans, Aborigines, and Latin American populations, and is common in Middle-Eastern populations as well. A small portion of the world population carries a rare variation of AB type subgroups that present weak reactions or no reaction at all to antibodies.

Another breakthrough of significance for both medical and forensic sciences was the discovery by Karl Landsteiner in 1940 that 85% of the human population carries erythrocytes that express the Rh(D) antigen, or Rhesus disease antigen (a protein also present in Rhesus monkeys). Blood is designated as being either Rh positive (⁺) or Rh negative (⁻). If an Rh⁺ person receives blood from a donor who is Rh⁻, his immune system will develop antibodies against the antigen, causing disease or death, depending on the quantity of blood transfused. There are thirty possible combinations between ABO groups and Rh factors. Approximately two thirds of all people have an O⁺ or A⁺ blood type, with all other types comprising the remaining third. These variations allow the number of suspects in a crime investigation to be narrowed.

Another singular characteristic of proteins and enzymes is the presence of discrete variations in a single base pair of the genes that encode them, known as polymorphisms (or multiple forms of the same gene). More than 1% of any given population has polymorphisms in specific genes. Specific polymorphisms are also more prevalent in certain populations. For instance, the CYP enzymes of the gene Cytochrome P 450 show a specific polymorphed version in 40% of the Asian population, whereas another polymorph is more prevalent among Caucasians and Europeans. Several other enzymes also present a known prevalence among races, and are therefore, useful in forensic testing.

Genetic screening for polymorphisms in forensic samples is very helpful when combined with blood type and Rh factors, because it sharply reduces the probability of the existence of two persons with the same blood characteristics being involved with the same crime to very insignificant odds. In addition, other serological tests can also be used to estimate age, sex, and race of suspects, such as hormonal levels in blood and other fluids, as well as genetic analysis such as chromosomal typing (or karyotyping), and DNA profiling.

SEE ALSO Animal evidence; Antibody; Antigen; Blood; Chromosome; Circumstantial evidence; Crime scene investigation; Cross contamination; DNA; Epidemiology; Fluids; Hemoglobin; Homogeneous enzyme immunoassay (EMIT); Illicit drugs; Immune system; Luminol; Parasitology; Paternity evidence; Saliva; Serum; Toxicological analysis.

**Serum**

Serum, or blood serum, is a useful medium for a range of forensic analyses, as well as for laboratorial diagnostic assays, due to its biological contents. Pure serum, however, does not contain blood cells, platelets, or fibrinogen (coagulation factors). The sticky consistency of serum is due to albumin, a protein that provides the proper density for blood, and prevents it from leaking through cell vessel walls. The main function of serum is to moisten the surfaces of cell membranes and to transport to organs and tissues diluted water-soluble nutrients such as blood red cells (erythrocytes), hormones, fat-soluble nutrients (chyle), white blood cells, and antibodies present in the lymphatic fluid as it enters the blood circulation. Serum is also present in seminal fluid and lymphatic fluids, and exudates from wounds and blisters as a clear watery substance. The presence of these and other contents in serum allowed the development of several types of analytical assays (tests) useful for both clinical and forensic purposes, such as for detecting tumor markers, detecting antibodies specific for infectious agents, anti-doping tests, blood typing, and DNA tests. Serological tests are also used in postmortem identification of poisons or illegal drugs in the body fluids of corpses.

Blood plasma is formed by serum and lymphatic fluid, and contains suspended leukocytes (white blood cells), erythrocytes, coagulation factors, electrolytes (e.g., mineral ions), gases, proteins, glucose, water, and micronutrients essential for cells. Plasma may contain poisonous metabolites resulting from enzymatic transformation of drugs, poisons, allergenic substances, or environmental pollutants, known as exogenous metabolites. Additionally, serum transports endogenous toxic