Forensic Serology
Forensic Serology

- The detection and the classification of various types of human bodily fluids such as blood, semen, urine, and saliva.
- A forensic serologist may analyze these bodily fluids in both liquid form and as dried stains.
- It can also involve the identification of bloodstain patterns at a crime scene, which cannot only tell who was present at the scene, but possibly what happened there.
History of Forensic Serology

- From 1950 to the late 1980’s, forensic serology was one of the most important parts of a crime lab.
- With the development of DNA techniques in the late 1980’s, more time, money, and significance was placed in developing DNA labs; Blood typing not as useful anymore.
- However, with limited funds and the time required for DNA testing, most labs still use many of the basic serology testing procedures.
The term **serology** refers to a broad scope of laboratory tests that use specific antigen and serum antibody reactions.

Blood typing falls into this category.

Karl Landsteiner - First person to recognize that all human blood is **not the same**.

Blood is distinguishable by its’ group or type.

Now called the **A-B-O System**.

Important because using the **wrong blood type** can cause instant death for those receiving transfusions.
Today there are more than 100 different blood factors (15 antigen typing systems) known.

In theory, no two individuals, except for identical twins, could have the same combination of all individual blood factors (not just blood types).

Blood factors are controlled genetically and have the potential of being a distinctive feature for personal identification.

Important in serious crimes where blood is found at a crime scene—homicides, assaults, and rape.
**Blood Characteristics**

- Complex mixture of cells, enzymes, proteins, and inorganic substances.
- **Plasma**: the fluid portion of blood...Mostly water; 55% of blood content.
- The other 45% is made of solid particles—Buffy Coat (Leucocytes & Platelets) & Erythrocytes
Blood Characteristics

- The 45% solid particles are:
  - Erythrocytes are red blood cells. They are responsible for oxygen distribution.
  - Leukocytes are the white blood cells; they are responsible for “cleaning” the system of foreign invaders.
  - Thrombocytes (platelets) are responsible for blood clotting. **Serum** is the liquid portion that separates from the blood when a clot is formed.
Important Parts of Blood for Forensic Science

- Red Blood Cells—because of their importance in blood typing.
- Serum—because of its’ importance in carrying antibodies.
- Proteins residing on the Red Blood Cell are called antigens.
- Antigens give blood-type characteristics to the Red Blood Cells.
- ABO and Rh systems are the most important blood types.
Blood Terminology

- **ABO blood groups**—based on having an A, B, both A&B, or neither A nor B antigens on red blood cell surface.

- **Antigen**—a substance on red blood cell that can stimulate the body to make antibodies. Certain antigens (proteins) found in the plasma of the red blood cells membrane account for blood type. (B antigen on cell membrane = Type B blood).

- **Antibody**—a substance in the serum that reacts with a specific antigen. (Antibody B reacts with B antigen).

- Anti-A is an antibody that is specific for the A antigen and will “go against” the A antigen and agglutinate or form a clump.
Blood Terminology

- **Agglutination**—clumping of red blood cells; will result if blood types with different antigens are mixed (Type A blood is mixed with Type B blood).

- **Rh factor (D antigen)**—may be present on red blood cells; Rh+ if D antigen is present and Rh- if not. Named after the Rhesus monkey.

- In routine blood typing, it is the presence or absence of the three antigens—A, B, D—that determines a person’s blood type.
<table>
<thead>
<tr>
<th>Anti-A</th>
<th>Anti-B</th>
<th>Anti-AB</th>
<th>A cells</th>
<th>B cells</th>
<th>O cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td><img src="image1" alt="Clumping" /></td>
<td><img src="image2" alt="No Clumping" /></td>
<td><img src="image3" alt="No Clumping" /></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td><img src="image4" alt="No Clumping" /></td>
<td><img src="image5" alt="No Clumping" /></td>
<td><img src="image6" alt="No Clumping" /></td>
</tr>
<tr>
<td>AB</td>
<td></td>
<td></td>
<td><img src="image7" alt="No Clumping" /></td>
<td><img src="image8" alt="No Clumping" /></td>
<td><img src="image9" alt="No Clumping" /></td>
</tr>
<tr>
<td>O</td>
<td></td>
<td></td>
<td><img src="image10" alt="No Clumping" /></td>
<td><img src="image11" alt="No Clumping" /></td>
<td><img src="image12" alt="No Clumping" /></td>
</tr>
</tbody>
</table>

**Agglutination**

Cells clumping together - agglutination

No clumping together – No agglutination
ABO Blood Typing

- **Blood type A** has antigen A on the surface of the cell and will agglutinate with blood type B.
- **Blood type B** has antigen B on the surface of the cell and will agglutinate with blood type A.
- **Blood type AB** has antigens A and B on the surface of the cells and will not agglutinate with either type A or B blood.
- **Blood type O** has neither antigen A or B and will not agglutinate with any blood type.
ABO Blood Types Visual

Blood Type A
- Antigen A
- Anti-B antibody
- Red blood cell

Blood Type B
- Anti-A antibody
- Antigen B
- Red blood cell

Blood Type AB
- Antigen B
- No antibodies
- Red blood cell

Blood Type O
- No antigens
- Anti-A antibody
- Anti-B antibody
- Red blood cell
## Blood Groups

<table>
<thead>
<tr>
<th>Type</th>
<th>Antigen on red blood cells</th>
<th>Antibody in serum</th>
<th>Can Give Blood To</th>
<th>Can Get Blood From</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A, AB</td>
<td>O, A</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>A</td>
<td>B, AB</td>
<td>O, B</td>
</tr>
<tr>
<td>AB</td>
<td>A and B</td>
<td>Neither A nor B</td>
<td>AB</td>
<td>A, B, O, AB</td>
</tr>
<tr>
<td>O</td>
<td>Neither A nor B</td>
<td>A and B</td>
<td>A, B, O, AB</td>
<td>O</td>
</tr>
</tbody>
</table>
Blood Types & Who They Can Give To

Universal Donor

O

A

B

AB

Universal Recipient
Universal Blood Recipient & Universal Blood Donor

 сохранили Type AB blood is known as the universal recipient (can receive blood from any type) because there are no A or B antibodies present to react with the types A, B, AB, or O blood.

Type O, which is the most common among humans, is known as the universal donor (can give blood to any blood type) because it has no antigens present to react with antibodies in A, B, AB, or O blood.
### Chapter 10

**Type O Universal Donor (no agglutination with all 4 types)**

<table>
<thead>
<tr>
<th>Recipient's blood</th>
<th>Reactions with donor's red blood cells</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ABO antigens</td>
</tr>
<tr>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>A</td>
<td>Anti-B</td>
</tr>
<tr>
<td>B</td>
<td>Anti-A</td>
</tr>
<tr>
<td>A &amp; B</td>
<td>None</td>
</tr>
</tbody>
</table>

**Type AB Universal Recipient (no agglutination with all 4 types)**
What blood type can a Rh+ person receive?

Rh+ person can receive Rh+ or Rh- blood. Rh- person can only receive Rh- blood.

There are no naturally occurring Rh antibodies in serum. However, anti-Rh antibodies can be produced upon exposure to the Rh antigen (i.e. Rh– person receives a blood transfusion of Rh+ blood).
# Population Distribution of Blood Types in the U.S.

<table>
<thead>
<tr>
<th>Type</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>45</td>
</tr>
<tr>
<td>A</td>
<td>40</td>
</tr>
<tr>
<td>B</td>
<td>11</td>
</tr>
<tr>
<td>AB</td>
<td>4</td>
</tr>
</tbody>
</table>
How common is your blood type?

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DISTRIBUTION</th>
<th>RATIOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>O +</td>
<td>1 person in 3</td>
<td>38.4%</td>
</tr>
<tr>
<td>O -</td>
<td>1 person in 15</td>
<td>7.7%</td>
</tr>
<tr>
<td>A +</td>
<td>1 person in 3</td>
<td>32.3%</td>
</tr>
<tr>
<td>A -</td>
<td>1 person in 16</td>
<td>6.5%</td>
</tr>
<tr>
<td>B +</td>
<td>1 person in 12</td>
<td>9.4%</td>
</tr>
<tr>
<td>B -</td>
<td>1 person in 67</td>
<td>1.7%</td>
</tr>
<tr>
<td>AB +</td>
<td>1 person in 29</td>
<td>3.2%</td>
</tr>
<tr>
<td>AB -</td>
<td>1 person in 167</td>
<td>0.7%</td>
</tr>
</tbody>
</table>

http://www.bloodbook.com/type-facts.html
Antigens and enzymes are genetically controlled

Genes: responsible for transfer of hereditable material

Genes are found on chromosomes, which are found in the nucleus of every cell
Genes Come in Pairs

- The position a gene occupies on a chromosome is called a locus.
- Genes for the same trait are located at the same locus on both the mother and the father’s chromosomes.
There are 3 alleles or genes for blood type: A, B, & O. Since we have 2 genes, there are 6 possible combinations.

<table>
<thead>
<tr>
<th>Blood Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA or AO = Type A</td>
</tr>
<tr>
<td>BB or BO = Type B</td>
</tr>
<tr>
<td>OO = Type O</td>
</tr>
<tr>
<td>AB = Type AB</td>
</tr>
</tbody>
</table>
Alternative forms of genes that influence a given characteristic are called alleles.

Made up of two similar genes

- AA: Homozygous
  - “Homo” means the same
- Aa: Heterozygous
  - “Hetero” means different
Blood Types are Genetic

- A and B Blood Types are Dominant
- Dominant: Characteristic is shown

- Blood Type O is Recessive
- Recessive: Characteristic is hidden

- Recessive characteristics only appear when both alleles are recessive
- i.e. Homozygous recessive OO
Phenotype V. Genotype

- **Phenotype**: individual’s outward characteristics
- **Genotype**: individual’s pair of allele genes together

Example:

- **Phenotype**
  - Type B Blood
- **Genotype**
  - Could be BO or BB depending on parents
Punnett Squares

- Mother: AB
- Father: BB

2 children out of 4 are AB = 50%

2 children out of 4 are BB = 50%

Genotype of a child with Type B Blood must be BB
Principles of Heredity

- Human Cells contain **46 chromosomes** with the exception of the egg and sperm, which contain only 23.
  - 23 of these chromosomes are inherited from **mother**
  - 23 of these chromosomes are inherited from **father**
Sex Chromosomes

- X-Chromosome: Female Sex Chromosome
- Y-Chromosome: Male Sex Chromosome

- **XX** individuals are female
- **XY** individuals are male
Unknown Stain at a Scene

Important Questions:

- Is it blood?
- From what species (human or animal) did the blood originate?
- If the blood is human, how closely can it be associated with a particular individual?
Preliminary Determination of Blood Tests that detect the hemoglobin in red blood cells

- **Hemoglobin**—a red blood cell protein that transports oxygen in the bloodstream; it is responsible for the red color of blood.

- **1.** Sample tested with 1 drop of phenolphthalein and then 1 drop of hydrogen peroxide. Turns deep pink color=Positive for blood (does not tell us species). Also known as the **Kastle-Meyer Test**
Preliminary Determination of Blood

2. Use of Hemastix (another test to use)

When moistened with distilled water and placed in contact with stain, a bright green color indicates blood.
3. **Luminol Test**

- Produces light if blood is present in a darkened area
- Extremely sensitive: can detect stains diluted up to 300X (i.e. 1 drop of blood in 300 drops of water)
- Will not interfere with any subsequent DNA testing
Luminol
Is It Human or Animal Blood?

- Microscopic observation – red blood cells differ in size with different species
Is It Human or Animal Blood?

- Precipitin test—
  - Human blood is inserted into animal (rabbit)
  - Rabbits produce antibodies to react against the human blood
  - Blood is drawn from rabbit that contains the human antibodies. This is used to produce human antiserum
Is It Human or Animal Blood?

Unknown blood sample, if human, will react with the human antiserum from the rabbit by forming a precipitate.
Testing for Semen

- **Stain** must be located and collected
- **Acid Phosphatase Color Test**
  - Purple color indicates the presence of semen

**Spermatozoa Test**
- Semen is diluted with water and dried on filter paper
- Microscopic examination looks for spermatozoa
Rape Evidence

- Presence of seminal fluid
- Physical injuries such as bruising or bleeding confirms a violent sexual assault took place
- Transfer of physical evidence—blood, semen, fibers, and hair—are usually present
Chapter 10

Collection of Rape Evidence

- All **outer** and **undergarments** are collected and packaged separately in **paper** bags
- Trace evidence is collected by standing on a **clean** sheet while removing clothing
- **Bedding** may be recovered if seminal stains are present

**Medical Examination of the victim**
Medical Examination of Victim

- Pubic Combings
- Pubic Reference Samples from victim
- Vaginal swabs and smear
- Rectal and oral swabs
- Head hairs
- Blood sample
- Fingernail scrapings
- All clothing
- Urine specimen
Medical Examination of Suspect

- All clothing
- Pubic hair combings
- Pulled head and pubic hairs for reference samples
- Penile swab
- Blood sample or buccal swab
Bloodspatter Pattern Analysis
Behavior of the Blood Drop

Blood Drop Size in relation to Height
Angle of Impact Matters!

How Bloodstain Pattern Analysis Works

angle of impact = \arcsin \frac{width}{length}

Blood droplet

(opposite side)

Width

Angle of Impact \theta

A

Surface

B

(hypotenuse)

Length

Chapter 10
What is the direction of travel of the blood?

Figure 5.7 Parent and satellite bloodstains (arrow shows direction of travel)

Jackson & Jackson: Forensic Science

© Andrew R. W. Jackson and Julie M. Jackson 2004
Chapter 10

How Bloodstain Pattern Analysis Works

Blood Drop Elongation

Angle of Impact

Blood droplet

Elongation of droplet occurs upon impact

90°  80°  70°  60°  40°  20°  10°

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Angle of impact

Decreasing angles of impact of single falling blood droplets.

Image used with permission from Stuart James, February 2007.
Area of Intersection and Convergence

The location of the blood source can be determined by drawing lines from the various blood droplets to the point where they intersect.

The area of convergence is the point of origin; the spot where the “blow” occurred. It may be established at the scene with measurement of angles by use of strings.
Area of Convergence & Angle of Impact

Chapter 10
Bloodstain Patterns

- Contact/Transfer
- Cast-Off
- Pool
- Radial
- Arterial Spurt
- Trail
Blood Pattern Reconstruction

Scene Pattern Reconstruction
1. Stain condition
2. Pattern
3. Distribution
4. Location
5. Directionality

Lab Results Reconstruction
1. Genetic marker typing
2. Age Determination
3. Source Determination
4. Race Determination
5. Sex Determination

—From “Cracking Cases” by Dr. Henry C. Lee
Blood Spatter Evidence

A field of forensic investigation which deals with the physical properties of blood and the patterns produced under different conditions as a result of various forces being applied to the blood. Blood, as a fluid, follows the laws of physics.
People of Historical Significance

Paul Kirk (1902-1970) was a professor of criminalistics and biochemistry at Berkeley in California. He actively assisted law enforcement organizations from 1935 to 1967. Dr. Kirk analyzed the blood stain pattern photos from the Sam Sheppard case and was instrumental in Sheppard’s release at his second trial. Find out more about the case at Courttv’s crime library.
Blood Droplet Characteristics

- A blood droplet will remain spherical in space until it collides with a surface.
- Once a blood droplet impacts a surface, a bloodstain is formed.
- A droplet falling from the same height, hitting the same surface at the same angle, will produce a stain with the same basic shape.
- How will the shape change as the height is increased or decreased?
A droplet contains approximately 0.05 mL of fluid.

Is not the same for all blood droplets, but is generally from 0.03 mL to 0.15 mL.

Size is directly dependent upon the surface or orifice from which it originates.

The impact area is called the target.

The average adult has about **FIVE** liters of blood inside of their body, which makes up 7-8% of their body weight.
Conditions Affecting Shape of Blood Droplet

- Size of the droplet; angle of impact
- Velocity at which the blood droplet left its origin
- Height

Texture of the target surface

- On clean glass or plastic—droplet will have smooth outside edges
- On a rough surface—will produce scalloping on the edges
Questions Answered by Blood Spatter Interpretation

- The distance between the target surface and the origin of blood
- The point(s) of origin of the blood
- Movement and direction of a person or an object
- The number of blows, shots, etc. causing the bloodshed and/or the dispersal of blood.
- Type and direction of impact that produced the bloodshed
- The position of the victim and/or object during bloodshed
- Movement of the victim and/or object after bloodshed
Bloodstain Terminology

- **Angle of impact**—angle at which blood strikes a target surface.
- **Bloodstain transfer**—when a bloody object comes into contact with a surface and leaves a patterned blood image on the surface.
- **Backspatter**—blood that is directed back toward the source of energy.
- **Cast-off**—blood that is thrown from an object in motion.
Bloodstain Terminology

- **Contact stain**—bloodstains caused by contact between a wet blood-bearing surface and a second surface which may or may not have blood on it
  - **Transfer**—an image is recognizable and may be identifiable with a particular object
  - **Swipe**—wet blood is transferred to a surface which did not not have blood on it
  - **Wipe**—a non-blood bearing object moves through a wet bloodstain, altering the appearance of the original stain
Bloodstain Terminology

- **Directionality**—relates to the direction a drop of blood traveled in space from its point of origin.

- **Terminal velocity**—the greatest speed to which a freely falling drop of blood can accelerate in air. It is dependent upon the acceleration of gravity and the friction of the air against the blood—approximately 25.1 feet/second.
  - **High velocity**—greater than 25 feet per second, usually 100 feet per second; gives a fine mist appearance.
  - **Medium velocity**—5 to 25 feet per second.
  - **Low velocity**—5 feet per second or less.
Bloodstain Terminology

HIGH VELOCITY IMPACT SPATTER
Bloodstain Terminology

Medium Velocity Spatter
Bloodstain Terminology

Low impact

• Low impact is really blood under the influence of gravity - it just falls.
Bloodstain Patterns

The shape of a blood drop:

- **Round**—if it falls straight down at a 90 degree angle.
- **Elliptical**—blood droplets elongate as the angle decreases from 90 to 0 degrees; the angle can be determined by the following formula:
Impact

- The more acute the angle of impact, the more elongated the stain.
- 90 degree angles are perfectly round drops with 80 degree angles taking on a more elliptical shape.
- At about 30 degrees the stain will begin to produce a tail.
- The more acute the angle, the easier it is to determine the direction of travel.
Bloodstain Patterns

- The harder and less porous the surface, the less the blood drop will break apart.
- The softer and more porous the surface, the more a blood drop will break apart.
- The pointed end of the blood stain faces the direction of travel.

Chapter 10
Blood Evidence

- **Class evidence** for blood would include blood type. **If you can determine the DNA you would have individual evidence.**

- Blood stain patterns are considered circumstantial evidence in a court room. Experts could argue many points including direction of travel, height of the perpetrator, position of the victim, left/right hand, whether the body was moved, etc.
Shh... it’s a secret... some of us are Secretors

80% of the population are secretors. Their blood-type antigens are found in high concentration in their body fluids such as saliva, semen, vaginal secretions and gastric juice. 20% are non-secretors.