CHAPTER 8
Forensic Medicine: The Inside Story

Confidential Correspondence

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II. Biological Evidence

Chapter 8: Forensic Medicine: The Inside Story

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8.1. Forensic Pathology and Medicine

Learning Goals and Objectives

Forensic medicine and anatomic evidence from a body itself can provide crucial information about the events leading to someone’s death. This information can be obtained through a variety of means including an external examination, an internal examination, referred to as an autopsy. In order to understand the stories that bodies can tell, you will need to demonstrate an understanding of:

- What aspects of medicine are involved in a medicolegal practice?
- What are the duties and training for coroners and medical examiners (pathologists)?
- What is meant by manner of death, cause of death, and mechanism of death?
- What are the classifications for manner of death and how are they determined?
- What is meant by postmortem interval, rigor mortis, livor mortis, and algor mortis?
- When are autopsies needed or required?
- What information can be gained from an autopsy and how are they performed?
- What are the major organ systems of the body investigated during an autopsy and what types of information can be learned from each?
- What are the major types of trauma and how are they characterized?

Hic locus est ubi mors gaudet succurrere vitae
(A motto often found where autopsies are performed meaning “This is the place where death rejoices to help those who live”)

INTRODUCTION

For as long as accidents, violence and injury have plagued humans, we have looked to the body itself to provide important clues as to what happened and how it occurred, especially when the victims cannot tell the stories with their own voices. While a body may not be able to “speak” with it’s own voice, it can tell volumes about what happened if we know how and where to look. In fact the word autopsy comes from the Greek meaning “seeing for oneself” – a reference to the medical process where the body reveals its injuries to a trained pathologist through careful examination. Finding telltale physical trauma or injury in a body, when coupled with a medical understanding of how these types of trauma can be caused, can shed light on the sequence of events that took place in a crime or accident.

In the previous chapter, we examined what types of key forensic information can be gained from the external biological structures of the body such as hair, skin and biometric anatomical features. In this chapter, however, we will look more carefully both inside and outside of the body specifically to allow it to “tell” us medical information of legal importance. The focus of this chapter will be on the forensic information that our organs and soft tissues can provide. Evidence relating to our bones and teeth, and the accompanying issues of the burial and postmortem fate (taphonomy) of human remains, is presented in the following chapter on forensic anthropology.

The field of forensic pathology is the branch of medicine charged with understanding the cause of death of a person. In trying to answer the central question of how a person died, we must look more closely at the information gained directly from an examination of the body, both external and internal examinations, and indirectly through biomedical imaging techniques.
**History**

The use of medical expertise and “surgical” techniques for examining dead bodies in an attempt to learn more about their deaths dates back thousands of years. The ancient Egyptians clearly connected medical observations with legal questions when the Grand Vizier Imhotep was appointed by Pharaoh Zozer to investigate deaths that occurred under suspicious circumstances around 2650 BC. Imhotep probably also wrote the very first medical texts in history, used medical ideas to investigate crimes, and experimented with new medical treatments that were quite remarkable for his time.

One of the first detailed written reports of a medicolegal death investigation comes from the Roman physician Antistius who performed an autopsy on Julius Caesar after Caesar’s assassination in 44 BC. Caesar was brutally attacked and left to die on the floor of the forum in Pompey by a group of between 5 and 10 conspirators. When Caesar’s body was carried home three hours later, Antistius indentified 23 distinct stab wounds to Caesar’s body, but found that just the second wound, an upward thrusting chest wound between the 1st and 2nd ribs, proved fatal. Another report from about the same period describes when the Roman physician Germanicus in 19 AD was employed to determine if a particular death was natural, as one group had claimed, or due to a deliberate poisoning, as claimed by other side, on the basis of the fact that victim’s heart would not burn – both side claiming that this fact supported their views.

While ancient and medieval records report medical dissections were done in particularly important legal cases, they appear to have been relatively rare and in some places entirely banned due to religious beliefs. In 13th century China, however, an important book by Sung T’zu, entitled *Hsi Yüan Lu* (sometimes translated as “washing away of wrongs” or “Instructions to Coroners”, Figure 8.1.1), was published in which a relatively comprehensive set of instructions for death investigations was provided. This book apparently was based upon centuries of earlier practice and was even routinely used well into the 20th century in China. This book stressed the complete and careful examination of the entire body and its wounds to see if they were consistent with witness statements, emphasizing cataloging the locations and types of wounds, identifying possible indicators for poisoning, and even using the observed state of the body’s decomposition and forensic entomology to arrive at a rough estimation of the time of death – relatively sophisticated considerations even by recent standards.

The use of a “crowners” – later to evolve into our modern term of coroner – in death investigations dates back well over a thousand years to medieval England. By the time of Richard I (1189-1199), the duties of the coroner were fairly well defined and included the physical examination of the bodies of all people who had died unexpectedly. Crowners rarely had any medical training or experience and autopsies were banned in England and most of Europe at the time due to prevailing religious beliefs. It was not until 1240, when the Holy Roman Emperor Frederick II opened the door to human dissection by first passing a law that a body could be dissected once every five years for teaching medical students, that dissections began to be a more generally accepted medical practice.

In medieval and renaissance Europe, medical-based investigations appear to still have remained relatively uncommon and typically reserved only for cases of unusual importance. The first recorded post mortem dissection of a suspicious death was performed by Bartolomeo of Varignana of Bologna in an autopsy of the nobleman Azzolino in 1302 after he had collapsed and died suddenly.
after eating. Azzolino’s body quickly became bloated, turned an olive color, and then ultimately became black. Azzolino had many enemies at the time and it was believed by some that he was poisoned. Bartolomeo, however, performed the autopsy and determined that the manner of death was from natural causes due to blood accumulation in the liver (probably veno-occlusive disease). Even though dissections were carefully controlled by law in renaissance Europe, there was a quite significant market for bodies destined for secretive dissection by medical students and artists. This market was supplied by grave robbers (sometimes called resurrectionists) – a practice that still, unfortunately, thrives today in various places worldwide (see the 2004 case of journalist and TV personality Alistair Cooke).

In 1530, an important set of laws was adopted, called the *Constitutio Criminalis Carolina* (based upon the earlier *Bambergensis* of 1509), that tried to unify the often vastly different criminal laws then existent throughout the Holy Roman Empire. The *Constitutio*, apart from other things, brought about several important changes relative to medicolegal investigations: it emphasized the importance of physicians in legal cases involving bodily injury, it dictated certain circumstances when medical information was required in court proceedings (such as murder, hanging, poisoning, drowning and abortion), and, for the first time, it gave courts the power to investigate crimes based solely upon the facts of the case and not be restricted solely to the claims of the litigants. Prior to the *Constitutio*, the courts could only deal directly with the accusations of victims without the chance to explore the claims further. In other words, in 1530 the courts were given inquisitorial powers, a fact that still often affects medicolegal practice worldwide.

In the 16th century, the French barber-surgeon Abroise Paré revolutionized surgical practice, primarily through his work in treating battlefield wounds and through his influence as the royal court physician. He felt strongly that anatomical knowledge was critically important to medicolegal practice worldwide.
physicians and published widely on his autopsies and dissections. His published case reports of medicine used in legal contexts, including specific directions on how to present medical legal information to courts, that became the first widely recognized texts on legal medicine. After his death, his work led to King Henry IV of France appointing skilled medical experts to make medicolegal investigations and report in all cities and royal jurisdictions.

The study of anatomy, aided by careful dissections, became more much more common in the 17th and 18th centuries (Figures 8.1.2 and 8.1.3) when medical practice became more fundamentally rooted in scientific observation and reasoning. As medicine matured, so did its application to legal questions. Forensic medicine began to be recognized as its own separate specialty. Giovanni Morgagni, considered by many as the founder of modern anatomic pathology, wrote an extensive work on pathology in 1769 called the “Seats and Causes of Disease Investigated by Anatomy”. In the late 18th century, the first textbooks arrived on the scene to guide medically trained investigators, led by Francois-Emanual Fodoeré’s three-volume treatise on legal medicine in 1799 and The Principles of Forensic Medicine by John Gordon in 1821. These works helped lead the way to understanding how injury could leave a set of observable features on a body that might be traced to a specific sequence of events, excluding other mechanisms for causing the observed trauma.

Today, forensic medicine is a centrally recognized discipline of medicine that has developed extensive standards and methods that work to ensure uniform practice based upon rigorous scientific principles applied to medicolegal investigations.

**Medicolegal Practice**

Medicolegal practice today represents a very broad range of work involving the application of medicine to inform legal proceedings. These applications can be quite legally complicated and include patient rights protection, malpractice liability, advance healthcare directives, mental competence, and injury and death investigations, among many others. The use of the term in connection with forensic science, however, is most commonly associated with medical investigations involving personal injury and the determination of the cause and manner of death. The distinction is often made, however, between clinical forensic medicine, where the victim is still living, and forensic medicine in which the victim has died. Examples of clinical forensic medicine include cases of non-accidental injury, abuse, assault, and rape, among others.

Pathology is the study of disease and disorders and is divided into two main branches: clinical and anatomic pathology. Clinical pathology deals with the diagnosis of disease that is usually based upon laboratory tests of body fluids and tissues. Anatomic pathology deals largely with the determination of disease or trauma based upon examination of the organs and tissues of the body. Forensic pathology is an important sub-specialty of anatomic pathology and usually focuses upon determining the cause and manner of death by physical examination of a body.

In the United States and elsewhere in the world, there are two systems of death investigation in common use: coroners and medical examiners. Coroners, as described previously, date back more than a thousand years to 10th century England and derives from a crown
officer ("crowner") entrusted with the oversight of all investigations involving human deaths, especially to ensure that the death taxes were paid to the King. Today, coroners are usually elected officials, generally in more rural locations, who are not typically required to have any specific medical training but who are legally responsible for overseeing death investigations. Coroners are not able to perform autopsies and their quasi-judicial actions are usually controlled by local and state regulations. In some locations, they can convene special inquests with juries to investigate and render a determination of the manner of an unknown or suspicious death. Occasionally, the duties of a coroner are coupled with other governmental positions such as that of a sheriff, district attorney, county health commissioner, or other official who performs the duties of the coroner in conjunction with their other responsibilities. In some locations, coroners are sworn law officers with the right to arrest suspects, issue subpoenas, and carry firearms, but this appears to be relatively uncommon.

Currently, ten states use only coroners as their death investigation officials and about another 30 employ a combination of coroner and medical examiner systems, depending upon the specific location in the state.

In the larger jurisdictions of cities and many states in the US, however, the medical examiner (ME) system has often replaced the older coroner system. A medical examiner must first be a physician, and almost always with special credentials as a board certified forensic pathologist. These highly trained physicians are able to perform autopsies to determine the cause, time, and manner of death. In the US, about 50% of the population is served by medical examiners and there are approximately 500 board certified forensic pathologists currently working. Any autopsies that need to be performed in a county with a coroner system are usually contracted out to nearby places with certified medical examiners. Unlike the frequent images depicted in TV shows, medical examiners do not always go to death scenes themselves. Specially trained death investigators often go to the actual location, take photographs, examine the body, and take charge of the remains before bringing it back to the medical examiner's office along with any associated evidence including drugs (illegal,

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**How to Become a Forensic Pathologist?**

Forensic pathologists are highly trained physicians, with deep knowledge of both medicine and various aspects of forensic science.

The training to become a forensic pathologist begins with four years of undergraduate studies followed by four years of medical school. After this, the new MD must spend four years, usually at a hospital, serving in something like an apprenticeship in clinical and/or anatomic pathology. Then, they need to spend a year or more on a forensic pathology internship or fellowship in a medical examiner's office working under the supervision of a trained forensic pathologist. During this time, they perform autopsies and other jobs of a medical examiner. Finally, they need to pass a comprehensive examination to become a board certified forensic pathologist. The entire process from entering college to board certification usually takes thirteen years of post-high school study and practice.

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**What’s in a NAME?**

The National Association of Medical Examiners in an organization for medical examiners engaged in the investigation of “sudden, violent and suspicious deaths, deaths related to public health and who perform autopsies” along with other medicolegal death investigators and administrators. The group seeks to practice “medicine in the finest tradition of preventive medicine and public health by making the study of the dead benefit the living.”
prescription, and over-the-counter), weapons, suicide notes, ligatures, and any other materials associated directly with the body. These investigators often serve as the liaison between the medical examiner’s office and the families of the deceased with law enforcement investigators.

The investigation of the cause and manner of suspicious and untimely deaths can help to resolve both civil and criminal legal disputes. Even when the cause and manner of person’s death may seem completely obvious, and autopsy must be performed to confirm the absence of foul play, to assist in any related police/legal investigation, or in relation to the transfer of assets of the deceased. For example, even though a gunshot wound may seem to be the obvious cause of death, an autopsy can confirm that a specific wound was the cause of death, recover bullets, collect vital trace and toxicology evidence and determine the trajectories of the bullets to aid in the investigation and crime reconstructions. Autopsies are also performed to ensure high quality medical care, educate young physicians and aid in the identification of new diseases. A recent study has shown that about one-third of autopsied patients had significant discrepancies between their clinical diagnoses made while they were living and the diagnosis at autopsy that would have made a difference in their ultimate survival. Understanding trauma from autopsies has also led to new and more effective methods for treating trauma patients and improving their survival rates. Finally, autopsies have helped to discover over eighty diseases or groups of diseases between 1950 and 1983, leading to significant advances in public health and safety.

**Medical Death Investigation**

The purpose of a death investigation is ultimately to determine how a person died. There are three important medicolegal questions that must ultimately be answered in any death investigation: the manner, the cause, and the time of death. Autopsies form only a part of the process of gaining sufficient information to answer these important questions. Other valuable information can be learned from a person’s medical history, details of the circumstances surrounding the death, items found near the body, and the state of the body (e.g., rigor mortis), among others.

Probably the two most important terms in the vocabulary of death investigation is **cause of death** and **manner of death**. These have very precise medical and legal definitions and it is important to understand the differences between these two terms.

**Manner of Death**: The term manner of death relates specifically to a determination of the intent or series of events that brought about the death and is classified into one of only just a few possible categories. These categories typically include: homicide, suicide, accident, natural, and undetermined. Some places also add therapeutic complications as a manner of death.
death, although this is not available in all jurisdictions, and where it is not an option, deaths from medical procedures are often placed in the natural category. It is important to note that the determination of the manner of death is primarily a legal determination, not a medical issue, although it is determined by a medical examiner or coroner. The distribution of deaths among the major categories for 2004 from the World Health Organization (WHO) is shown in Figure 8.a.5. It is important to note that the causes of death, however, vary greatly by age groups. For example, the leading cause of death in young adults is primarily from accidents while those of older adults is primarily natural causes (Figure 8.1.6).

**Homicide** is defined as a death caused by another individual, whether by intent, through negligent actions, or inadvertently. In legal proceedings, we differentiate between the level of intent used to bring about someone’s death by deciding whether is was on purpose, leading to murder and homicide charges, or without intent, usually leading to manslaughter charges if the offender was determined to be negligent. For example, the planned shooting or drowning of someone would lead to a murder charge while someone bringing about a fatal heart attack through an abduction or by the unexpected discharge of a firearm could be charged with manslaughter. Nonetheless, the manner of death in all of these cases is simply homicide – a death brought about by the actions of someone else for any reason (Figure 8.1.7).

**Suicide** is a death brought about intentionally by the person who dies themselves in an effort to end their own lives. Suicide is illegal, as is usually assisted suicide facilitated by another person. It may be difficult to determine, however, whether a death was a suicide or brought about by another manner of death, but information about a person’s background, medical history and mental state at the time of death can help provide important clues. Suicides vary greatly depending upon age groups, as shown in Figure 8.1.8. There are some “conventions” that are typically used by medical examiners where an apparent suicide might be classified as an accident or

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**Table 8.1.1.** Leading causes of accidental deaths in the US in 2002.

<table>
<thead>
<tr>
<th>Leading Cause</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicle crashes</td>
<td>44.3</td>
</tr>
<tr>
<td>Unspecified non-transport</td>
<td>17.8</td>
</tr>
<tr>
<td>Falls</td>
<td>13.6</td>
</tr>
<tr>
<td>Poisoning</td>
<td>13.0</td>
</tr>
<tr>
<td>Drowning</td>
<td>3.9</td>
</tr>
<tr>
<td>Fires and burns</td>
<td>3.4</td>
</tr>
<tr>
<td>Other land transportation</td>
<td>1.5</td>
</tr>
<tr>
<td>Medical complications</td>
<td>2.2</td>
</tr>
<tr>
<td>Firearms</td>
<td>0.8</td>
</tr>
<tr>
<td>Natural disaster</td>
<td>0.8</td>
</tr>
</tbody>
</table>

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natural. For example, the death of a person who knowingly engages in dangerous and reckless behavior and then dies from a fall is usually classified as an accident, while a terminally ill patient who refuses to eat and dies of malnourishment is usually classified as a natural death. In both of these examples, it could be argued that the person’s death arose from knowingly engaging in actions that would bring about their own deaths and could, therefore, be classified as suicides.

**Accidental** deaths arise from a violent, unexpected death that was not caused by any intentional or criminal act by another person. Accidental deaths are, unfortunately, very common and Table 8.1.1 shows the leading causes of accidental death in the US. Accidental deaths account for about one-fourth of all deaths for people 25 - 44 years old and over one-third of all deaths of children. Traffic-related deaths, by far the largest single cause of accidental deaths, are usually classified as accidents when collecting statistics relating to deaths. Additionally, deaths from natural disaster are considered natural deaths, as shown in Figure 8.1.9.

The category of a natural death accounts for the largest overall number of deaths by far and is the result of a naturally occurring illness or disease such as heart disease (25% of total deaths), cancer (23%), stroke (6%), birth defects (classified as such even if the decedent died at an old age), SIDS, and influenza, among many other. Figure 8.1.10 shows the ten major causes of death, with nine of the top ten coming from natural causes. Natural deaths occur between 90 and 95% of all deaths (averaged over all age groups, 2009 CDC statistics).

Occasionally, it is very difficult or impossible to determine the manner of death, either from lack of evidence or the result of very complicated issues associated with the death – for example, more than one factor at work. In these cases, the manner of death may be listed as **undetermined** when a classification cannot be reasonably made. The determination of a manner of death often has important legal consequences, including criminal charges, such that a medical examiner may choose to wait for more evidence and use this classification until the case become clearer. Many medical examiners feel that it is better to have the manner of death remain undetermined for a period of time, in some cases even indefinitely, rather than change a classification of manner of death later on. The courts always, however, have the right and responsibility to change the manner of death as more information becomes available since there is no statute of limitations of human deaths.

In some places, the additional category of therapeutic complication (sometimes referred to as “medical misadventure”) is used to indicate that a death occurred due to known and often predictable side-effects from appropriate medical procedures. It is important to note that cases in which a person dies because of the misapplication of standard medical practice are not part of this category and

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*Figure 8.1.9. Accidental causes of death from natural disaster*

*Figure 8.1.10. Major causes of natural deaths in the US in 2005* (Retrieved 10 April 2009 from CDC Leading Causes of Death 2005 Table C http://www.cdc.gov/nchs/FASTATS/kod.htm).
should be classified as homicides. Also excluded from this category are cases in which well-intentioned mistakes, including incorrect diagnoses, lead to death: these are properly classified as arising from a natural manner of death. Where this classification does not exist, the medical examiner must decide on whether it should be classified as a natural death of a homicide – usually they are determined to be a natural death. In the US, estimates range from about 50,000 to 100,000 deaths would fall in this category annually (Institute of Medicine).

The **cause of death**, unlike manner of death, is solely a medical determination and relates to the disease or injury that actually brings about the death of the person. The cause of death can be thought of as the medical condition that ultimately leads to a person’s death. The **mechanism of death** is the actual biochemical or physiologic means by which a person dies. For example, if a person sustains multiple impact injuries from an automobile accident, the cause of death could be determined to be blunt force trauma with the mechanism of death being exsanguination (loss of blood). The independent issue of manner of death could be determined to be homicide, accidental or suicide in this case, depending upon other evidence. Occasionally, a pathologist may identify a **contributing cause of death** or **proximal cause of death** to provide additional information about the death. For example, our accident victim could have had seizures causing them to “black out” that might have had an effect on the death. The contributing cause, in this case, could be epilepsy.

It is important to know that in our legal system injuries always take precedence over disease for determining the cause of death. For example, a person could have severe heart disease long before they might have been mildly assaulted. In a normal person, the assault might have caused little more than a bruise but in this case, it could have triggered a heart attack that led to the person’s death. The cause of death in this instance would be determined to be from blunt force trauma (the assault), with heart disease a contributing cause with the manner of death determined to be a homicide. Since there is no statute of limitations on homicide, injuries sustained in an attack might not result in a death for many, many years and still have the death determined to be a homicide. For example, if a person is shot and recovers but dies from pneumonia twenty years later, it might be determined that the death was caused by the older gunshot injury (a form of blunt force trauma) with pneumonia as the contributing cause to lead to a manner of death determination of homicide.

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**Two Minute Mystery**

**Case:** A motorcycle accident leaves a man with a fractured tibia that is set in the hospital and the person recovers. Over a number of years, however, an infection of the broken bone sets in that ultimately develops into a cancer in the open space left in the bone by the original accident. The cancer goes undetected for years and is identified only after it metastasizes (spreads) elsewhere in the body. The cancer eventually kills the man more than twenty years after the original motorcycle accident.

**Problem:** If you were the pathologist in this case, what would you determine to be the cause, manner, and mechanism of death (and contributing cause if possible) in this instance?

**Cause:** accidental; **Manner:** could be several things resulting from the cancer such as hematoma or edema; **Mechanism:** metastatic squamous cell carcinoma; **contributing:** chronic osteomyelitis [infection].
Time of death. The time of death is a valuable piece of information in any death investigation. A variety of methods have been developed and new techniques are on the horizon for improving our estimates of time of death when it is uncertain. Several biochemical markers, such as ion concentration in the vitreous humor of the eye and protein release into the bloodstream, have already been presented in a previous chapter and are useful indicators of the Post Mortem Interval (PMI) – the time between the actual death and the time that the body was found. Additionally, the use of other indicators, such as insect life found on or around the body and the stage of decomposition of the remains, is very useful for longer periods of time, up to months and even years, and will be discussed later in chapter 10. Nonetheless, forensic pathologists are often called upon to use evidence from the body to determine time of death, especially in the first 72 hours after death.

Determining time of death usually requires an estimate of the postmortem interval (PMI). If you know both when the body is discovered and the PMI, you can back-calculate to determine the actual time of death. Forensic pathologists have methods that can be fairly accurate to determine the PMI within about the first 72 hours of death: rigor mortis, algor mortis and livor mortis. The time of death, however, usually involves a range of times – the longer the PMI, the larger the range (or the uncertainty in the time).

Rigor mortis, probably the best known measure of the PMI that is found throughout the popular literature, is a stiffening of the muscles of the body after death, as illustrated in Figure 8.1.11. While there is a fair amount of variation depending upon the individual and conditions, some important trends are very helpful in determining the PMI from rigor mortis observations.

Rigor usually begins about 4 and 6 hours after death, reaches a maximum between 12 and 24 hours after death, and lingering effects can last for as much as 72 hours before the tissues are fully relaxed again. The effects of rigor first are first observed in the smaller muscles, such as the jaw, fingers, and toes, before it becomes noticeable in the larger muscles of the arms and legs.
legs. Rigor mortis also affects the muscles of the skin and hair follicles to produce “goosebumps” (called *cutis anserine*) – their presence does *not* reflect the temperature of the surroundings at time of death. As rigor is released, the larger muscles soften first, followed by the smaller one. Observing these differences can help determine how long rigor mortis has been in effect.

Unlike when we flex our muscles, rigor mortis does not occur through the shortening of muscle tissues. When we flex our muscles in life, small structures in our muscles, called sacomeres, contract by causing the long protein filaments of actin and myosin to slide by each other to shorten the sacomere, Figure 8.1.12. Energy, in the chemical form of ATP, is then required in order overcome this shortened arrangement by forcibly moving calcium ions around to relax the sacomeres in the muscle back to starting point. In the case of rigor mortis, however, the energy needed to “unlock” the sacomeres and allow them to relax is not available after death and the sacomeres become “locked” in the “on” (shortened) position. It is only after the proteins themselves decompose sufficiently that the muscles begin to relax and rigor mortis passes off of the body.

**Livor mortis,** also known as lividity, is observed as dark red to purple discolored areas of the skin (and internal organs) that arises after death (Figure 8.1.13). It is caused by the blood settling into the lowest regions of the body due to the effect of gravity after the heart stops beating to produce the evenly distributed coloration. The effect occurs because the tiny blood capillaries in the skin dilate (open up) after death. If pressure is put on parts of the body where the blood is pooling, such as lying against the floor or an object, the blood will not settle there and the skin will appear lighter ("blanched") than the surrounding tissues. During the first eight to twelve hours after death, the blood is free to move and resettle someplace else if the body is shifted or pressure is put on a region of lividity. After this time, the color becomes “fixed” due to the congealing of the blood and constriction of the tiny capillaries such that the blood no longer moves freely if the body is placed into a new position. The presence of “fixed” lividity that doesn’t match up with the position of the body can indicate that the body...
was moved well after death.

Lividity may be decreased or even absent in cases of extreme blood loss or anemia in the person (decrease in the number of red blood cells). Lividity may also be difficult to observe in people with dark skin coloration.

**Algor mortis** is the slow cooling of the body after death. Normal body temperature is 98.6° F (37° C), well above the ambient temperatures of most surroundings. Once someone dies, therefore, the body begins to cool since there are no biochemical reactions or mechanisms operating within the body to maintain the living body temperature, until it reaches thermal equilibrium with its surrounding (when the body temperature and the surrounding temperature are about the same). If we know how fast a body cools and since we know the temperature of the body at the moment of death (usually), we can estimate roughly the time it took to cool to the observed temperature giving a good estimate of the PMI. The temporary heat generated through decomposition can slow this return to ambient temperatures.

Generally, the body cools at a rate of about 2.0 to 2.5° F (1.1 to 1.4 °C) per hour for the first few hours with an average rate of about 1.5° to 2.0° F (0.8 to 1.1 °C) per hour averaged over the first twelve hours, slowing to about 1.0°F for the following six hours. Many factors contribute, however, to significant variations in this cooling rate such as clothing, the surroundings (e.g., temperature, moisture, humidity), the amount of body fat, diseases, where the body was found (e.g., in water, buried, in the sun, etc), and, as will be explored in chapter 10, insect activity. An example is shown in Figure 8.1.14 showing the cooling over time for several different body masses. Algor mortis is certainly a useful indicator for the time of death but is only a rough guide and can be affected by many conditions that are hard to quantitatively account for.

**When Are Autopsies Performed?**

The internal organ systems of the body can provide vital information needed to determine the causes and manner of death. When this is necessary, a pathologist examines the body closely and collects samples for appropriate laboratory tests to provide the missing information. An autopsy, as defined by the National Association of Medical Examiners (NAME), is “primarily a systematic external and internal examination for the purposes of diagnosing disease and determining the presence or absence of injury [including the] chemical analysis of body fluids for medical information as well as analysis for drugs and poisons.” An autopsy occurs under a very specific set of circumstances when the dissection of a person’s remains is required to provide information as to the circumstances surrounding their deaths that cannot be determined through other means. Sometimes, it may be decided that sufficient information is available to answer these questions without an autopsy. Local and state laws typically govern when autopsies are required. The usual times what an autopsy is required often include:

- Any unattended or unexplained death when a physician is not available or is unwilling to sign a death certificate;
- Any unexpected death that takes place under unusual, unexplained, or suspicious circumstances suggesting foul play;
- Any death resulting from homicide, suicide, or certain types of accidents (e.g., vehicle accidents, falls, drowning, burning, ingestion of poisons, etc);
- Any death from a disease or other agent that could pose a risk to the public health, including contagious diseases and toxins;
- Any death that takes place while the person is in legal custody, incarceration, or confinement;
- Any employment or occupational-related death;
- Any death of an institutionalized person for reasons other than illness or known disease;
• Any death from a standard “lower-risk” medical procedure (e.g., anesthesia, surgery, dental procedures, standard therapies, etc);
• Any hospital death when the person is pronounced dead on arrival or occurring within the first 24 hours of being admitted to the hospital unconscious;
• Any death that appears to be the delayed result of a previous injury, especially when the injury resulted from criminal actions against the person (e.g., assault resulting in seizures, pulmonary embolism, heart attack, poisoning, etc.);
• Any death where the body will be cremated and not available for future exhumation.

There are, of course, other circumstances when an autopsy is performed. For example, it might be desirable for a family to learn more about the medical cause of a particular death to confirm the diagnosis about a suspected disease or illness that might have a helpful impact upon the long-term health of the living. This could provide information about the presence of inherited diseases such as cancer, kidney disease, heart disease, or Alzheimer Disease. In this instance, the family can request an autopsy to focus on providing this potentially useful information.

There are also times when, due to religious, cultural, or ethical grounds, a family might not wish to have an autopsy done. Medical examiners certainly try to accommodate these wishes as far as it is possible legally, but when the law requires an autopsy, the legal requirement for autopsy almost always takes precedence. Sometimes, the extent of the autopsy can be limited as a compromise. For example, the autopsy might be limited to just the chest organs or only the brain. The pathologist tries to make it such that the effects of the autopsy can be concealed so that open casket funeral or other religious ceremonies are often still possible.

Relatively few deaths actually require autopsies, however, typically ranging between 10 and 20% of all investigated deaths. Autopsies are...
most common for younger people, Figure 8.1.15, and for those involved in violent crimes, Table 8.1.2.

Information from an Autopsy

Dr. Lester Adelson proposed that an autopsy is something like an interrogation (The Pathology of Homicide, 1974, Chas. C. Thomas, publ.) where the pathologist seeks to discover answers to six important questions from the deceased. These key questions are:

1. **Who are you?** One of the first questions that needs to be answered is who the body belonged to. This is usually determined by a number of methods that includes: (1) visual identification by a friend or family member, (2) identifying materials found on the body (e.g., ID card, jewelry, passport, or other papers), (3) physical markings on the body, such as scars, birthmarks, and tattoos, (4) comparison of X-ray or similar biomedical scans (e.g., dental X-ray, chest X-ray, MRI, CAT, etc), (5) fingerprint comparison, and (6) DNA comparison analysis. Visual identification and items found on the body are often remarkably unreliable and are rarely used as the sole means of identification. The best identification, of course, involves DNA testing, but there are some limitations of DNA uses already discussed in the DNA chapter, especially when there is the lack of a DNA sample from a known person suitable for comparison. This can especially arise if the person is completely unknown rather than using DNA to verify a suspected identification.

2. **When did you become ill or hurt and when did you die?** Answers to these questions can come from a variety of sources including those already discussed including rigor mortis, livor mortis, and algor mortis. Other physical markers can also be used to inform us when an injury occurred. For example, bruises can help to determine when an injury might have occurred since bruises (contusions) typically change color as they heal, often going from a purple/blue color (1 to 18 hrs), through a blue/brown color (~1 to 2 days), then to green (~2 to 3 days), and finally to a yellow color (~3 to 7 days) before fading completely, assuming a healthy person (Figure 8.1.16). Signs of healing of a wound and how far the healing has progressed could indicate how much time might have elapsed between the injury and death.

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**Why do sailors get tattoos?**

Getting a tattoo is a very common experience that sailors throughout naval history share. The origin of this “tradition”, however, comes from the straightforward need to provide a ready method for identifying the bodies of the sailors after horrific sea battles. These battles involved closely confined quarters and very destructive cannons that frequently resulted in severe trauma such that an easy means of body identification was needed – if nothing more than to keep track of who was aboard. Tattoos provided an easy, decorative, personalized, and inexpensive permanent marking on a sailor’s body to provide a degree of permanent identification. This practice of personalized tattoos today still provides medical examiners with useful pieces of evidence in postmortem body identification.

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### Introduction to Forensic Science

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*Draft 2/11/12*  
*J. T. Spencer*
Additionally, the stage of digestion of contents of a person’s stomach can also indicate when their metabolism was stopped by death, suggesting the length of time between the last meal and death. These findings during the autopsy can be reinforced or brought into question by information that is not determined at the autopsy but comes from other sources, such as the person’s last known sighting.

3. Where did you get hurt and where did you die? A great deal of information regarding this question can come directly from the death scene rather than from the autopsy but the information often informs the pathologist’s investigation. Incident reports, hospital records, and emergency medical accounts can provide valuable information. Medical information provided by the medical examiner, however, can certainly help to confirm or refute theories. For example, unusual livor mortis patterns that are inconsistent with how the body was found can help show that the body was moved some hours after death. Finding unexpected items within the body cavity can also suggest a place of death. For example, pollen found in the sinus cavity can be compared with plants in the area to suggest a possible location that the person visited recently. The field of forensic taphonomy, covered in Chapter 9 on forensic anthropology, deals with how remains decay and are moved, distributed, or otherwise disturbed after death.

**Common Terms involved in an Autopsy**

- **Decedent**: the person who has died.
- **Laceration**: occurs with pressure splits open the skin to produce uneven wounds, such as from a blunt force impact.
- **Contusion**: is a bruise usually caused by an impact that damages blood vessels and causes them to leak into the surrounding tissue.
- **Hematoma**: is a blood tumor with a significant amount of blood collection.
- **Blunt force trauma**: trauma caused from the impact of a non-penetrating object, such as from a bat, a car, or the floor.
- **Sharp force trauma**: trauma caused by a sharp object such as a knife, often a form of penetrating trauma.
- **Incision**: a cut wound that is longer than wide, usually caused by drawing a sharp object across the skin.
- **Stab or puncture wound**: a cut or piercing wound that is wider than long, caused by a stabbing motion with appointed object.
- **Abrasion**: is a wound caused by rubbing or scraping an object across the skin – usually involves just the outer layers of the skin.
- **Gunshot**: Penetrating wounds from a high velocity projectile from a firearm of similar device.
- **Ligature**: a thread, rope of cord
- **Embolism**: the obstruction of a blood vessel.
- **Edema**: swelling from fluid accumulation.
4. **Did you die as a result of an accident, violence, natural causes or some combination of reasons?** The answer to these questions results in the determination of manner of death with much of the key information coming from the autopsy itself. Each organ, wound, and injury is carefully examined during the autopsy, with the intent of determining the manner and mechanism of the death. Evidence from the autopsy can also be deemed consistent with or differing from a suspected cause of death.

5. **If violence was completely or partially responsible for your death, was it from suicide, accident, homicide, or other reasons?** In this question, the pathologist focuses upon any wounds or injuries found on the body. They begin by determining the type (laceration, incised or cut wound, puncture, abrasion, contusion, or gunshot), size (length width, depth), and location of the wound. The direction of the wound is also important and can often be determined from the shape of the wound or injury.

6. **If someone killed you, who did it?** This is often not the role of the pathologist but they can provide important clues for investigators that can support or refute a suspect’s story of the events.

Answers to each of these questions provide an important piece of the puzzle in determining how someone died. In the next section, we’ll explore what happens during an autopsy and how vital information can be discovered through this process.

**The Autopsy**

A complete autopsy proceeds along a series of well orchestrated steps to systematically examine the body, inside and outside. An autopsy can involve the entire body or be restricted to just one area, such as the head or chest. Throughout the autopsy process, plenty of photographs and notes by the pathologists are key to their ability to use the medical evidence gained during the procedure in court. And, of course, the safety of the pathology team from injury and infection is of paramount importance.

In this section is presented the generalized steps often employed during a complete autopsy. Sometimes there is variation in the order and extent of the steps due to the condition of the body or the specific information sought.

**Step 1 – Access and Control of the Remains:** This may seem like an obvious step, but especially in a criminal investigation, the body is itself considered to be physical evidence and subject to a rigorous chain of custody process. Typically, the body is placed into a new “body bag” at the death scene and sealed with “tamper-proof” tags to ensure that it arrives at the medical examiner’s office intact and untouched. As with all evidence, proper records, photographs, and narrative are important for keeping track of the evidence. If there is a gunshot possibility, the decedent’s hands are often covered to prevent contamination or loss of the evidence. Care is also taken at the crime scene to recover potentially valuable evidence closely associated with the body itself, such as clothing, fluids, medications, etc.

**Step 2 – External Examination:** Before any cutting begins, a very careful external examination of the entire body is made. The overall health and description of the person (e.g., sex, hair color, weight, length, eye color, ethnicity, age, etc.), including clothing, any penetrating objects, and stains, are detailed first. All marks, scars, etc.
signs of trauma and other visible features are recorded and photographed. Wounds and injuries are located on the body and measured, including direction of any penetrating wounds. If emergency medical intervention or hospital procedures were performed, the results of these actions are also carefully recorded. Often, the fingernails are scraped, hands tested for gunshot residue (GSR), fingerprints rolled, fibers collected, and samples of any other interesting materials on the body are taken (e.g., glass fragments, paint chips, soil samples, etc). X-ray images are usually taken, and increasingly other biomedical scans are employed, such as MRI and CT scans. These methods of biomedical imaging will be discussed in greater depth later in this chapter.

**Step 3 – Opening the Thoracoabdominal (thorax and abdomen) and Brain Cavities:** In this step, the pathologist typically begins by making a “Y-shaped” incision across the chest, starting near each shoulder, coming together at the lower end of the sternum, and then down the abdomen to the pubis (missing the navel), as shown in Figure 8.1.17. Bleeding from these cuts is very small since the blood moves only in response to gravity. The skin is then folded back to expose the ribs and sternum (breastbone). The sternum and the front parts of the ribs are then removed, often with a Stryker saw—a motorized saw designed to efficiently cut through bone (Figure 8.1.18). This type of incision provides good access to the chest cavity and neck without disturbing the face, arms and hands.

The brain cavity is then opened by making an incision behind one ear and then across the top of the skull to the same point behind the other ear. The two flaps of skin of the scalp are separated by pulling one flap forward over the face the other backwards over the nape of the neck. The skull is then cut along the nape of the neck, joining the cuts behind the ears. The cut skull cap can then be removed to expose the brain. The brain is first observed in place and then removed for further study.

**Step 4 – Removing Organs:** Once the chest and thorax have been opened, the organs are removed for measurement and examination. The organs can be removed one at a time or all together in a “bloc”. Each of the organs are weighted, measured, carefully inspected and dissected for signs of disease or trauma. During this process, the pathologist usually takes many samples of tissue and fluid from numerous places for later examination and chemical analysis.

The careful evaluation of the major organs of the body forms an important part of the internal autopsy examination. These major organ systems will be considered shortly in terms of their function and evaluation during an autopsy.

**Step 5 – Evaluation and Analysis of Sample:** One of the most time-consuming, and often most valuable, steps of an autopsy involves the careful examination and analysis of the tissue and fluid samples recovered during the procedure. Tissues samples are prepared into microscopic samples and studied for abnormal shapes and structures, indicating conditions such as cancer, congenital defects, and others. The fluids are usually analyzed for controlled substances, toxins, alcohol, proteins, and other chemical compounds, depending upon the suspected cause of death.

**Step 6 – Closure:** At the end of the autopsy, the pathologist usually places the organs back into the body cavity, replaces the sternum and skull cap, and the incisions stitched are up so as to show as little evidence as possible of the procedure (“baseball” stitch). This usually allows funerals, including open casket services, to proceed without visible signs of the autopsy to be noticeable.
Samples removed from the body must be preserved properly and stored (chain of custody) for extended periods, sometimes up to twenty five years by law. After all samples have been recovered and the procedure completed, the body can then be released to the family or mortician for burial.

**Major Organ Systems Examined**

As described above, the major organ systems are typically removed from the body during the autopsy and subjected to careful examination. Pathologists are particularly concerned with identifying any structural abnormalities, diseases present, or signs of injury of violence that could have contributed to the person’s death. These major organs studied include:

- **Heart**: The heart is the center of our circulatory system and is responsible for pumping about 2,000 gallons (7,500 liters) of blood throughout the entire body each day! It beats about 100,000 times every day and requires only about 20 seconds to pump a portion of blood through the entire circulatory system. A typical adult heart weights about 300 g and is somewhat larger than the size of a clenched fist (Figure 8.1.19). During the autopsy, it is removed and separated from the lungs, weighed, and inspected—especially the blood vessels on the outside of the heart (coronary arteries). If the heart is unusually large, it can indicate the presence of a condition known as hypertension or high blood-pressure—a condition where the heart must work extra hard to pump blood through the blood vessels. The heart is usually dissected to examine the inner structures and occurs in the order of blood flow, from right atrium to right ventricle to left ventricle and ending with the left atrium. Throughout the process, the pathologist looks for anything unusual relative to a normal, healthy heart and search for evidence of infection,
damaged tissue and valves, and blocked arteries, especially the coronary arteries. Any potential damage to the large veins and arteries around the heart, such as the aorta and vena cava, is also explored.

It is obvious from this that the pathologist must have a very detailed understanding of the structure of both a normal heart as well as how the organ changes with disease or injury. This, of course, is likewise true for the other organs of the body.

• **Lungs:** The lungs are responsible for both oxygenating and removing carbon dioxide from the blood. The lungs exchange these gases between our blood system and the outside air, exchanging over 2,000 gallons (7,500 liters) of air in a day. The lungs are composed of an intricate network of blood vessels and mucus-lined air passageways, arranged like the branches of a tree (Figure 8.1.20). They are organized with one lung on either side of the heart (the left lung is slightly smaller than the right due to the placement of the heart). Once removed, the pathologist inspects the lungs for fluid, foreign materials, growths, and discolorations. Lungs are also inspected for embolisms—an object, such as a blood clot, that moves through the body and blocks blood flow in a vessel. Often, these emboli form in the veins of the legs, arising from extended bed rest, disease, or trauma to the legs, and move to the lungs where they can produce fatal blockages. The pathologist also looks for signs of infection, pneumonia, smoking-related diseases, and tumors.

• **Liver and Gall Bladder:** The liver is a very large organ with multiple functions that include glycogen storage (an energy reserve molecule made when our bodies have excess glucose so that our cells can be powered even when we are not actively taking in any calories—especially when we sleep), removal of waste products from
the blood, protein production, and other key biological functions. A typical healthy adult liver weighs about 1.5 Kg (~3 lb) and is bright red. Some diseases, such as cirrhosis, which can arise from chronic alcohol consumption, cause the liver to become very fatty, yellow, hardened, and dysfunctional (Figure 8.1.21). A number of other serious conditions of the liver, including cancer, necrosis (dying tissue), hepatitis, and many others, can be found upon liver examination. The liver also produces bile, a chemical that aids in the digestion of fats and lipids in the body. Excess bile is stored in the gall bladder when not needed for digestion. The gall bladder can become inflamed, infected, carry “gall stones”, or a variety of other problems that can be revealed during an autopsy.

- **Stomach and Intestines**: The stomach is a key organ of the digestive system that continues the digestion process of food that begins in the mouth and it starts the absorption of nutrients into the blood stream (Figure 8.1.22). The small intestines are attached to the stomach (about 6 m, or 20 feet, long) and lead into the large intestines (about 1.5 m, or 5 ft, long). During an autopsy, the contents of the stomach are examined to learn both what the person last ate and to gain a rough indication of how long before after eating they died. Pill casings, poisons and toxins can sometimes be found in the stomach and intestines, suggesting a possible suicide from drug overdose. Various diseases, such as cancer, ulcers, and blockages, are also looked for during the examination. During the autopsy, the intestines are removed and the entire length examined for obstructions, disease or trauma.

- **Kidneys, Bladder and Urinary System**: The pair of kidneys, each weighing about 150 g and about 4 inches long, form a key part of the urinary system, although they also play important roles in blood chemistry regulation, hormone secretion, and control of the body’s blood pressure (Figure 8.1.23). Healthy kidneys appear dark red with a very smooth surface. As with the liver, they are dissected to look for any signs of disease, blockage, or trauma that might be observed. The bladder holds urine until it is released from the body through the urethra. Urine is usually sampled for later toxicological studies.

- **Spleen**: The spleen is an important part of our immune system, central to the production of both red and some types of white blood cells.
The spleen is sensitive to trauma and is often compromised or ruptured from impact trauma such as car accidents, leading to internal blood loss through hemorrhaging (Figure 8.1.24).

- **Pancreas:** The pancreas is about five inches long in an adult and is located “behind” the stomach (toward the spine, Figure 8.1.25). Its key function is the production and regulation of insulin and several important digestive enzymes that are required to convert our food into cellular energy. Failure of the body to produce sufficient insulin, or an inability to properly respond to insulin, results in diabetes. Long-term diabetes that has not been well controlled can result in a variety of severe problems including heart disease, nerve damage, weight loss and many others. Recently, an estimate of between 15-20% of all autopsies involved patients with diabetes. Other diseases of the pancreas, including cancer, pancreatitis (an inflammation of the pancreas), and cystic fibrosis would be detected at autopsy.

- **Neck:** The organs of the neck, especially the esophagus, larynx, tongue, epiglottis, and thyroid are usually removed and examined (Figure 8.1.26). The pathologist looks for unusual growths, malformations, or cancers. In addition, if strangulation is suspected, the small and somewhat fragile hyoid bone in the neck is often found to be broken and is checked to see if it is damaged.

- **Sex Organs:** The uterus in women and the prostate in men are removed and dissected to see if any tumors or other unusual features are present. Additionally, undetected pregnancies are looked for. These organs are usually not weighed.

- **Brain:** The adult brain, typically weighing around 1.4 Kg (3 lbs), usually appears smooth and white on the inside and grey on the outside portions with numerous blood vessels crisscrossing throughout (Figure 8.1.27). Once removed, the brain is usually preserved in fixative for a week or more to firm it up prior to dissection. Blunt trauma, including car crashes and other head injuries, can lead to hemorrhaging of the blood vessels in the brain. Elsewhere in the body, a region surrounding any hemorrhage can easily swell to relieve the pressure build up from the accumulating fluid. Think, for example, of a swelled lip or ankle after an injury, the tissue surrounding to the injured area is able to expand to accommodate the fluid build up. In the brain, however, the inflexible, rigid skull bones prevents this expansion from happening. This tightly restricted space stops the body’s ability to freely swell around a brain hemorrhage can lead to a dangerous build up of pressure in the brain, causing blood supplies and vessels to be compressed and even completely shut off, leading to tissue death.
This effect is referred to as compartment syndrome and is a rapid onset, life-threatening problem common with brain injuries. A similar effect can be seen with brain aneurysms, ruptures or “ballooning” of weakened blood vessel walls in the brain. Brain tumors can also be readily seen as smooth and distinct from the surrounding brain tissue. Autopsies also remain the best method to confirm a diagnosis of Alzheimer’s Disease in older patients (Figure 8.1.28).

Gunshot wounds can lead to blackened and torn tissue through the brain, allowing pathologist to track the path of the projectile.

Common Types of Trauma

Some types of injuries are so common that they require a more detailed and specific description. Generally, injuries can be broadly divided into two large groups that revolve upon whether they are penetrating or non-penetrating wounds. Penetrating wounds include projectile wounds, such as from bullets, arrows, and flying debris, and sharp force trauma, such as may arise from knives, glass and similar. Non-penetrating wounds include blunt force trauma, such injuries often sustained from vehicular accidents, falls, or assaults, and asphyxia, such as from strangulation or suffocation.

(1) Firearm Injuries: Firearms vary greatly in terms of the size, shape and force that a projectile can impart to a body when struck at high velocity. Details about firearms themselves will be presented in much greater detail in a later chapter but a special consideration of the types of wounds that they inflict are important in forensic pathology. The term terminal (or wound) ballistics is usually applied to the course and effects of a high speed projectile, such as a bullet, when it impacts...
a body. There are several mechanisms by which tissue damage occurs from a bullet strike (Figure 8.1.29). The first is the obvious direct impact of the bullet on tissue along its path as it travels through the tissue (sometimes called “tissue crush” or “permanent cavity damage”), illustrated in Figure 8.1.30. The second damage mechanism, often referred to as temporary cavitation (or tissue stretch), arises from the brief cavity formed behind the bullet as it move at high velocity through tissue by pushing the tissue outward and away from the bullet’s path, as seen in 8.1.31. Note that the “sonic wave” from a bullet does not, however, have any real impact on tissue damage (consider the therapeutic lithotripter used to break up kidney stones with sonic waves is 2,000 times stronger than a bullet’s sonic wave without any tissue damage). The sonic wave, shown in Figure 8.1.32, can have a neurologic effect upon the victim, causing shock and disorientation. The amount of damage from temporary cavitation depends upon what tissue it affects; stretchy tissues, such as the lungs and skin, can show little damage from temporary cavitation while solid organs, such as the liver, aorta, heart and kidneys, can show great damage. Larger and slower bullets typically crush more tissue than smaller, faster projectiles with the same kinetic energy, while the faster bullet will stretch more tissue with relatively little direct (crush) damage.

A bullet can impart a significant amount of energy to the body as it moves through the tissue from its kinetic energy (KE) which is dependent upon the mass and the velocity of the bullet (KE = \( \frac{1}{2} mv^2 \), where m is the mass of the
projectile and \( v \) is its velocity). The kinetic energy of a bullet increases as the mass or velocity of the bullet increases. If a bullet is stopped entirely by the “target”, then the entirety of its kinetic energy is delivered to the target. Bullets, therefore, vary in the amount of kinetic energy that they can deliver, with a .50 caliber bullet delivering about 12 times the amount of energy as a .22 caliber bullet with just a doubling of the diameter of the projectile. Once a bullet impacts bone or tissue, it may not follow a straight path due to its tumbling and yawing (rotation around the long axis of the bullet) motions. When the bullet strikes bone, the direction of the bullet can often be determined by the beveling of the bone it passes through (see the next chapter on Forensic Anthropology). The amount of tissue damage observed is a complex combination of projectile features that includes its shape, velocity, pathway through tissue, whether it deforms on impact, and many other features.

Details of gunshot wounds can be used to identify an entrance from an exit wound (if it does exit at all), providing information about the direction of the shot. Entrance wounds are typically much smaller than exit wounds, although not always (Figure 8.1.33). Because of the tumbling or yawing that a bullet may experience after striking tissue and the elasticity of the skin, it is usually not possible to determine the size (or caliber) of the bullet from the size of the entrance wound. There is great variation in size and shape of gunshot wounds, depending on the corresponding size, shape, velocity, and trajectory of the bullet when it strikes the body. There are four general types of entrance wounds: contact, intermediate range, distant range, and atypical wounds.

Contact wounds occur when the muzzle of the gun is either placed directly on or very close to the skin (< 2 in.). This type of wound often leaves visible soot and searing of the skin with a possible muzzle impression left behind on the skin. Intermediate range wounds come from the muzzle placed between two inches to 2 feet from the victim and usually leaves a stippling effect on the skin (small “spots” from unburned or hot gunpowder from the shot, Figure 8.1.34). It may be possible to estimate range of the shot from the diameter of stippling pattern. Distant shots are considered to occur from shots at ranges greater than two feet and usually can leave clean, star-shaped wounds. Atypical wounds occur from grazing, surface lodged, or other unusual types of impacts.

Exit wounds are often irregular, large and lacerated. Exit wounds can sometimes be differentiated from entrance wounds by looking at bone beveling – the exit side of the bone will show a “crater” of larger diameter than the entrance side (Figure 8.1.33 and also see forensic anthropology chapter).
Shotguns produce quite different wounds from single projectile weapons (e.g., rifle, handgun). Shotguns usually use many smaller projectiles (typically pea-sized or smaller) in a single burst that disperse once they leave the barrel of the gun, as shown in Figure 8.1.35. The body can show a circular pattern of wounds and the diameter of the wound pattern can be used to estimate the distance between the gun and the victim.

(2) Drowning/Asphyxia: Death by asphyxia, lack of oxygen, can occur from drowning, accidental or intentional suffocation, and strangulation, among others.

Drowning deaths are usually caused by fluids entering the lungs, preventing their normal gas exchange function. In the US, drowning is the 2nd leading cause of death for children under 12. Deaths in water can occur from natural causes other than drowning (e.g., heart attack, seizure, etc.), from prior injury or injury while in the water, or specifically from drowning. Drowning usually involves a victim initially holding their breadth, which increases their blood carbon dioxide levels that triggers involuntary breathing. The victim then swallows water leading to convulsions, loss of consciousness, and death within 3 to 4 minutes. Drowning can also occur with relatively little water found in the lungs. This can happen from sudden cardiac arrest or a laryngeal spasm (tight closing of the larynx in the throat) upon shock of falling into the water. Near-drowning, when someone is revived while unconscious, can also be fatal and presents a serious medical threat. Occasionally, diatoms (small organisms with hard skeletons found if water, Figure 8.1.36) or other water-born matter can be found in the lungs, sinuses, or elsewhere that indicates that drowning is the cause of death.

(3) Blunt Force Trauma: Blunt force trauma, probably the most common types of injury, refers to injuries arising the forceful action of a non-penetrating object on a body, such as from a fist.
Figure 8.1.37), foot, bat, hammer, pipe, fall, or similar object. The amount and type of injury depends upon the amount of force delivered \((F = ma)\), how quickly the force is delivered, where on the body the injury occurs, the health of the victim, and other factors. Types of blunt force trauma include abrasions, contusions, laceration, and fractures, discussed previously (Figure 8.1.38).

(4) Sharp Force Trauma: This type of penetrating trauma refers to injuries arising from stabbing, cutting and wounds that enter the body, such as those that arise from a knife, rod, or similar sharp object. Both stabbing and cutting (incised) wounds involve slit-like injuries but an incised wound is usually longer than wide or deep and a stab wound is deeper than long. The normal elasticity of the skin can often make it very difficult to determine much about the weapon used to cause incised wounds, although some important inferences can be made, especially whether a particular weapon is capable of producing observed wounds on a victim. Careful dissection can often tell the depth, width and direction of a stab. Of particular concern in assaults is the presence of defensive wounds – wounds usually on the hand and arms as the victim tried to shield themselves from the attacker by extending their hands and arms outward,

(5) Vehicular Trauma: Vehicular trauma can be though of as a special case of blunt force trauma to drivers, passengers, and pedestrians resulting from the injuries received involving a motor vehicle. Worldwide, this type of trauma accounts for more than 1.2 million deaths annually. The evaluation of vehicular trauma involves consideration of often complex human, vehicular, and environmental factors, such as biological effects from drug use, psychological issues such as depression and suicide, vehicle repair, and driving conditions). The most common types of injuries encountered are brain/head injuries and broken bones.

(6) Fire-Related Deaths: Deaths associated with fire are typically handled as suspicious until evidence suggests otherwise, although the majority of house fires are accidental. Burns are classified into 1st, 2nd, and 3rd-degree burns depending upon their depth and severity (Figure 8.1.39). Third-degree burns can be very deep and involves charring of the skin. In cases of death by burning, bodies largely consumed by fire typically assume a “pugilistic attitude” – a boxer-like pose where the knees and elbows are bent and the hands clenched - caused by dehydration of the body tissues. Internally, the organs may show signs of extreme heat damage (similar to cooking). Toxicology and autopsy results are important to determine if the person died before the fire in an attempt to disguise the death.
The lungs at autopsy might show significant damage from smoke inhalation while toxicology reports might show higher than normal CO\textsubscript{2} or CO levels in the blood.

(7) **Sudden and Unexplained Deaths:** This category is not a true form of trauma but involves the same type of careful detective work by the pathologist as is used in dealing with death investigations from trauma. Sudden, unexpected and unexplained deaths (SUD) encompass a great deal of medical territory. Generally, they are defined as those that arise either from a brief illness resulting in death before a diagnosis can be made or from a longer illness that does not have a satisfactory diagnosis. Usually, no apparent trauma is externally visible. Upon autopsy, these types of deaths can be found to arise from many, many causes. An autopsy involving these types of deaths can also often provide important medical information to the living by indicating the presence of hereditary or congenital diseases. These types of deaths are relatively uncommon in both the young, who typically die from either well-known health problems or through accidental deaths, and the old, who often die from longstanding, well-diagnosed chronic problems. Thus, they are most common in adults from 25 to 65 years old. The list below presents just a very few possibilities for SUD that can be discovered during autopsy.

- **Cardiovascular Problems** – this category represents the predominate cause of sudden and unexplained deaths through cardiac arrest, myocardial infarction, atherosclerosis (thickening of blood vessel walls), hypertension (high blood pressure leading to an enlarged and inefficient heart), and other heart and circulatory problems.

- **Intracranial Lesions** – These include epilepsy, aneurysms (weakening of a blood vessel’s wall, often leading to the rupture of the blood vessel and hemorrhaging), brain malformation (e.g., hydroencephaly), trauma or disease induced hemorrhage (loss of blood from the circulatory system), tumors, meningitis, and others.

- **Respiratory Causes** – These include severe bronchitis, emphysema, asthma, pulmonary tuberculosis, lung cancer, pulmonary embolism (blockage), pneumonia, influenza, pneumothorax (collapsed lung), and others.

- **Metabolic Disorders** – This encompasses many disorders including diabetic coma, hormone problems, insulin shock, and others.

- **Psychiatric Patients** – This category includes delirium syndrome, choking, others.

- **Urogenital, Gastrointestinal, and Spleen** – This includes problems involving kidney tumors, bladder cancer, peptic (bleeding) ulcer, perforated ulcer, peritonitis (inflammation of the inner lining of the abdomen), sickle cell disease, and others.

- **Miscellaneous** - This category is very large and includes SIDS (Sudden infant death syndrome), tubal pregnancy, artery erosion, undiagnosed tumors, and others.

![Types of burns and damage levels.](Image)

**Figure 8.1.39.** Types of burns and damage levels.
others. There are certainly instances when, even after an autopsy and complete laboratory analysis, the medical cause of death remains a mystery.

Once the autopsy and death investigation has been completed, the medical examiner must communicate his or her findings to both the family and the governmental officials (e.g., law enforcement, prosecutors, health department, etc) through a formal death certificate. This document provides, beside identification information of the victim, details about where, when and the cause and manner of death of the person. Additionally, in the case of finding of homicide or suicide, the medical examiner may be called upon to testify in court about their work.

Mass Disasters (DMORT)

On rare occasions, medical examiners may be called upon to deal with situations that involve more than one death from a particular series of events, such as hurricanes, earthquakes, floods, transportation crashes, explosions, and acts of terrorism, among others. Mass disasters are defined in several ways but most commonly simply as a manmade or natural disaster that exceeds the local capacity to deal with it. In the US, there are a number of both public and private agencies that deal with disaster relief. In terms of forensic pathology, the Disaster Mortuary Operational Response Team (DMORT) is a Federal governmental response unit that works with local coroners and medical examiners to assist in their work of the recovery, identification and death investigation of human remains. It is composed of forensic, medical, and other death professionals (e.g., morticians) that aid local work in many ways including search and recovery, mobile morgue operations, forensic examinations, sample acquisition, burial and family assistance.

Death of a Comic

Steve Allen, one of the most famous comics in the early days of television and the first host of the “Tonight Show” died unexpectedly in 2000. On the way to his son’s home in California for dinner one evening, he had a very minor “fender-bender”. There were no apparent injuries and, after exchanging insurance information with the other driver, he arrived safely at the dinner party. Shortly after arriving, however, he said he felt unwell and went to take a brief rest. He was found a short time later unconscious and pronounced dead, from a presumed heart attack, at a local hospital.

The autopsy found that the cause was not a heart attack. Apparently, the minor accident had ruptured a blood vessel in Allen’s chest that allowed blood to leak into the sack surround Allen’s heart, called the pericardium. As the sack filled with blood, it placed pressure on the heart that leads to an inefficient pumping of blood by the heart and, ultimately, death. Without the autopsy, the wrong cause of death would have been listed. What do you think should be the correct manner of death in this circumstance (it was ruled accidental by the coroner in LA)?

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Death from a Small Ball: Lincoln Autopsy

On the day that Abraham Lincoln died, April 15, 1865, his body was autopsied at noon in the White House, in what is now the President’s dining room. The partial autopsy focused solely upon his brain. During the procedure, the skull was opened and the brain was carefully removed. When the brain was lifted out, however, the round bullet, having traveled from behind the left ear to just behind the right eye, dropped out. Eight government officials were in attendance that day and, during the procedure, Mrs. Lincoln sent in to the doctors to have a lock of the president’s hair removed for remembrance – a common tradition of the time (that’s where our term “locket” comes from, a place to preserve a lock of a loved one’s hair). An excerpt from the official report of the surgeon, Dr. Curtis, stated:

“There was a gunshot wound of the head around which the scalp was greatly thickened by hemorrhage into its tissue. The ball entered through the occipital bone about one inch to the left of the median line and just above the left lateral sinus, which it opened. It then penetrated the dura matter, passed through the left posterior lobe of the cerebrum, entered the left lateral ventricle and lodged in the white matter of the cerebrum just above the anterior portion of the left corpus striatum, where it was found.”

“The wound in the occipital bone was quite smooth, circular in shape, with beveled edges. The opening through the internal table being larger than that through the external table. The track of the ball was full of clotted blood and contained several little fragments of bone with small pieces of the ball near its external orifice. The brain around the track was pultaceous and livid from capillary hemorrhage into its substance. The ventricles of the brain were full of clotted blood. A thick clot beneath the dura matter coated the right cerebral lobe.”

Curiously, in recent years some physicians and historians have argued quite persuasively and with reasonable evidence that Lincoln was dying at the time of the assassination from a hereditary cancer and that he would not have survived long and would have died very soon anyway of natural causes (it’s been suggested that he was suffering from either Marfan syndrome or Multiple Endocrine Neoplasia). These ideas have been suggested by the death mask and period photographs of Lincoln that show an increasing dissymmetry of his face and skull. Current theories strongly favor Multiple Endocrine Neoplasia as the culprit, which often presents in facial, especially lip shape, changes with gastrointestinal problems, well-know to have been problems for Lincoln. This theory could be confirmed from a tissue sample from Lincoln but his body is well entombed, making a tissue sample unavailable for analysis [Lincoln is entombed safely behind tons of cement after an 1876 attempt to steal his body for ransom from his vault in Springfield, Ill.]