scenes: A delicate green tendril snaking through a sun-bleached skull. A tree growing down through a shallow grave in the woods. A flush of growth marking the outlines of an inexplicably fertile corner of an abandoned lot. Each became yet another promising measure of the seasons that follow "death most foul."

*Mordre wol out* (murder will out), Chaucer's fourteenth-century prioress declared. "But those who work in homicide investigation, forensic pathology, and criminal law know better," mocked former U.S. Attorney General Ramsey Clark in his 1973 preface to *Spitz and Fisher's Medicolegal Investigation of Death,* forensic pathology's enduring bible. "The true manner of death which may have been murder is not determined in tens of thousands of cases annually in our violent land," Ramsey continued. "The cost to the nation in truth, justice, health and safety is enormous."

Ironically, it may be a return to Chaucer's touching faith in the constancy of nature that gives forensics its long-sought-after Holy Grail. It may well be that nature trumps technology in producing death's infallible stopwatch.

*Corpse* is the story of this pursuit and journey—the birth of a trio of natural sciences that together address what might be called the forensic ecology of human remains. It is likewise an account of their long road to acceptance in the courtroom, their maturation, their recent triumphs, and their future challenges. Like the smell of death that clings to the nostrils for days on end, it is a story that piques and haunts.

# I The Body Handlers

*The psychiatrist knows nothing and does nothing*
*The surgeon knows nothing and does everything*
*The pathologist knows everything . . .*
*but is always a day too late.*
—TRADITIONAL MEDICAL MAXIM

THE TYPICAL AMERICAN goes into the ground injected with three to four gallons of preservatives. But a sizable segment of even our oversanitized culture will always escape quick processing. Prominent among this population: the abandoned and the murdered. In theory, their moldering bodies—slumped under bridges, forgotten in bed, or dumped along roadsides—retain the natural if repulsive clues that might disclose time of death. For reasons as sensible as sensory, police are quick to pass these unvarnished dead to the next in line of custody—the coroners and medical examiners whose job it is to coax secrets from a corpse.

Many trace the work of forensic pathology—the medicolegal investigation of death—to the ancient Greeks who, circa 380 B.C., began dissecting various animal carcasses and applying their findings—at times absurdly—to humans. Greeks physicians did perform the rare human dissection. But Hippocratic writings express a deep disdain for the business, even as they named it: *autopsy.* Despite its strange implications of self-examination, the term has resisted 2,000 years of scientific lobbying to replace it with the more logical *necropsy.*

The Egyptians, meanwhile, suffered no such Hippocratic qualms. Historic accounts of anatomy and pathology classes at the Museum of Alexandria in the third and fourth century B.C. describe not only autopsies but also the live dissection of criminals "for the study, even while they breathed, of those parts which Nature had before concealed." Among the Greek and Egyptian observations were descriptions of death's first known clocks: *rigor mortis,* or postmortem stiffening, and *algor mortis,* body cooling. Unlike their nineteenth-century counterparts, who would chart the stiffening and cooling with hour-by-hour muscle testing and body-core thermometers, the ancients were satisfied with the postmortem touch test that homicide detectives still use today:

Warm and not stiff: Not dead more than a couple hours
Warm and stiff: Dead between a couple hours and a half day
Cold and stiff: Dead between a half day and two days
Cold and not stiff: Dead more than two days.

The physiology behind the rigidity and cooling rate would elude understanding for two millennia. In the meantime, scientists and nonscientists alike clung to many postmortem myths supplied by the early Greeks and Egyptians. Among them, the belief that rigor could make a corpse sit up in bed or clench its fists in undead rage. (In reality, rigor causes muscles to stiffen, not actively contract.) The ancients also misinterpreted a legitimate artifact of rigor—that of hair standing on end—as a sign that whiskers and curls continued to grow after death. If that were true, they would have discovered a postmortem clock that could literally be measured with a ruler. Today, pathologists understand that a cadaver's hair at times *appears* longer because of the stiffening of the tiny



muscles surrounding each hair follicle. The same phenomenon can produce a set of head-to-toe goosebumps that has *nothing* to do with what the victim saw at the moment of death.

History records the first known application of medical knowledge to death investigation in 44 B.C. Summoned to examine the body of Julius Caesar, the Roman physician Antistius announced that he knew which of the would-be emperor's twenty-three stab wounds had proved fatal. By clocking death to a particular blow, Antistius thwarted the plot by which the Roman senators had hoped to avoid any *one* of them standing trial for murder. In the end, history tells us, they all paid with their lives. But Antistius's historic death determination, however dubious it may have been, marked the beginning of the pathologist's role as expert witness to murder. In fact, it gave us the term *forensic,* Latin for "before the forum," which is where Antistius made his fateful declaration.

Meanwhile, half a world away, a nonmedical system of death investigation had taken root in China. Bamboo slips unearthed at sites dating to the Ch'in dynasty (221–207 B.C.) detail the procedures that civil servants were required to follow when summoned to examine a corpse found under suspicious circumstances. China's state-ordered death investigations grew in sophistication during the progressive Sung dynasty (A.D. 960 to 1279), culminating in the earliest known forensic handbook by Hsi Yuan Chi Lu, *The Washing Away of Wrongs,* in 1247.

In it, the death investigator Sung Tz'u describes how to ascertain time of death in each of the four seasons, by assessing the extent of a corpse's decomposition. He notes, for example, that during the cool months of spring, a visible reddening of the mouth, nose, and belly indicates a postmortem interval of two to three days. "After ten days, a foul liquid issues from the nose and ears," he continues, cautioning the homicide detective to take into consideration the build and previous health of the victim. "In fat and swollen people it is like this. Those long ill and emaciated will display these symptoms only after half a month."

In summer, the same sort of purging from the nose and mouth postmarked death three days past, with hair falling out on the fourth or fifth day. By contrast, freezing weather slowed decomposition to a crawl. "During the three winter months, when four of five days have passed, the flesh of the corpse will turn yellowish purple. After half a month, the symptoms [reddening] described above will appear." In general, Sung Tz'u instructed death investigators to multiply by five days the time required for the colors and smells of decomposition to appear in winter as compared to summer. Although the rubric ignored the many hidden factors that could speed or slow human decay, it accurately captured the pivotal role of bacterial growth, which accelerates in warm weather to hasten the breakdown of soft tissue.

Sung Tz'u refrained from attempting to pinpoint time of death to any window narrower than a day or two. His discretion appears all the more wise, given the long distances China's thirteenth-century death investigators had to travel on foot to cover their large districts. More often than not, their examinations involved bodies in advanced stages of decomposition. Yet even the crude postmortem markers of advanced decay could help sort a list of suspects by alibi and opportunity. More important, perhaps, a time-stamped trail of corpses gave the Sung constabulary some hope of tracking down the roving gangs of bandits that plagued thirteenth-century China, with its population of 100 million spread over a land area comparable in size to that of western Europe.

Yet Sung Tz'u and his students rendered their opinions without the benefit of any medical training. Indeed, physicians played little to no role in ancient Chinese homicide investigations, a situation that Asian legal scholar Brian McKnight attributes to their low social status. In this aspect, Chinese forensics had a clear counterpart in the nonmedical coroner system that appeared in England in the tenth century. McKnight even suggests a direct influence, with information about the Chinese system passed to England by way of the well-traveled courtiers of Sicily.



In any case, we know that in 925, King Athelstan appointed the English noble St. John of Beverly to be the first "keeper of the please of the crown," an unwieldy title soon truncated to "crowner" and eventually "coroner." Then as now, the legal basis for the coroner system was to "enquire where, *when,* and by what means, a person came to his death." Admittedly, the Old English coroner's need to postmark death had more to do with record keeping than criminalistics. Registering the death date for a person who died in his sleep required the coroner to ascertain whether that person expired before or after midnight. The official chronometer in such cases would have been the back of the coroner's hand held against the corpse to judge its warmth or lack of it. Occasionally, such determinations had material consequences, as when brothers or other joint heirs died in battle, with all inheritance passing to the family of the last to die.

Outside such time judgments, the ancient coroner's primary interest centered on signs of suicide, a crime against God and king that resulted in forfeiture of the victim's estate, a handy source of royal income that spelled destitution for survivors. Unfortunately, the dire consequence of this duty quickly led to the coroner system's corruption. By Shakespearean times, the coroner's susceptibility to bribes had become a well-known joke, as illustrated in act 5, scene 1, of *Hamlet,* in which two grave diggers laugh at the crowner's pronouncement that Ophelia's suicidal drowning had been accidental—owing to the water coming to her, not her to the water. Historical records suggest that Shakespeare lifted this twisted bit of logic from an actual coroner's ruling of his day.

England's corrupt coroner system would prevail throughout the British Empire, including present and former colonies, for centuries—greatly slowing medical advances in death investigation. Expanding the scientific roadblock was the Council of Tour's twelfth-century condemnation of autopsy as "an abomination against God."

Yet in the face of all this, the first quasi-medical examiner system appeared in 1532, when Emperor Charles V decreed that medical testimony be part of all trials involving "homicide, infanticide, abortion, or poisoning" throughout his Holy Roman Empire of central and southern Europe. Their new role in legal proceedings gave Europe's early anatomists new legitimacy. It also gave them reason to look differently at the cadavers they had been secretly dissecting to better understand the living. Could the cold flesh also reveal the manner and timing of its death?

By the end of the century, the French physician Ambroise Paré had recorded Europe's first official criminal autopsies, describing among other things the lungs of deliberately smothered children (fluid-filled and speckled with blood). Over the next generation, the new field of forensic medicine came into being with the publication of a succession of studies, culminating in Paolo Zacchia's *Quastiones Medico-Legales.*

Importantly, Paré, Zacchia, and their contemporaries added to rigor and algor a third postmortem timepiece: lividity, or livor mortis, from the French *liviere,* "to turn blue." What they had documented was the gradual deoxygenation and gravitational settling of the blood that begins as soon as lungs and heart cease their motions. Importantly, lividity—with its clear and predictable procession of hues from pink through purple to blackish-blue—presented a stopwatch visibly set in motion within minutes, not just hours, of death.

The color progression of lividity begins with the proverbial pallor of death in an already light-skinned person, as blood begins to drain out of the upper surfaces of the body. As soon as fifteen to twenty minutes after death, an experienced observer can see the first diffuse blotches take form on the underside of the body. The seepage likewise becomes visible in dead-end crannies such as earlobes and skin folds. Within an hour or two, the telltale discoloration becomes obvious to even the untrained eye. The pink "slap" of early livor gradually darkens to a dull, bruiselike red before progressing through shades of purple and blue as oxygen gradually disappears from the blood.



However, the lividity is not yet "fixed," or permanent. Press your thumb against an area of livor in the first hours after death, and it will blanch. Similarly, should you move the body during this period, the blood-settling patterns will shift, though perhaps not completely, for livor's fixation is not all or nothing, but gradual. A body dead in a kitchen chair at 5 P.M., then undressed and tucked into bed at 8 P.M. may retain the faintly blanched impressions of contact points between the body and unyielding surfaces such as the back of that chair or a tight waistband.

By ten hours past death, lividity's stain has become fully fixed. The body has now cooled to the point where the fatty lining of the blood vessels congeals, pinching shut the tiny capillaries near the body surface. The dark stain of blood seepage can no longer escape inward when pressed, nor will it resettle, even partially, when the body is shifted. Moving a body once livor has fully set leaves behind a stark and permanent imprint of death's original position. Oftentimes, the detail can reveal the very texture of the surface on which the victim dropped—be it the stippled inscription of a gritty path, the weave of a carpet, or the design of kitchen linoleum. (Indeed, the pale imprint of the toilet seat across the buttocks of heart-attack victims helped twentieth-century pathologists recognize the heightened danger of cardiac arrest in the minutes immediately after rising from bed.) Even after fixation, the stain of lividity may continue to darken, reaching its maximum intensity around twelve hours postmortem. It will remain prominent until overwhelmed by the colorful creep of bacterial putrefaction.

In the late 1700s, the French pediatrician and chemist Pierre Nysten revisited the postmortem muscle lock that the Greeks had dubbed rigor mortis. Like others before him, Nysten noted that death initially released all hold on the muscles. The body slumps, utterly flaccid, before gradually stiffening in the hours that follow death. He was the first, however, to build a clock out of the joint-by-joint progress of the subsequent rigidity. The result, in 1811, was the first scientific description of rigor mortis and "Nysten's law," which states: "The progress of cadaveric rigidity is descending." That is to say, it begins with the muscles of the face, then progresses to the neck, trunk, arms, and finally the lower limbs. Nysten concluded that the pattern reflected the increasing distance between different muscles and the brain, although he puzzled over the fact that decapitation didn't seem to affect the process. It is now known that the general progression of joint paralysis is actually from smaller to larger muscle groups. But that understanding—as well as an appreciation of rigor's many vagaries—would only come with the twentieth-century discovery of the biochemical wonders of muscle movement.

Meanwhile, the simplicity of Nysten's law gave early forensic pathologists a deceptively precise chart of time since death. The generally accepted timetable began with the first signs of jaw stiffness an hour after death and wrapped up with the lock of hips and knees ten hours later. The twelfth hour brought "full rigor," a fascinating state in which the body appears fully petrified. Rest the head on one chair and the feet on another, and the corpse will remain suspended like some bewitched volunteer in a vaudeville magician show. At typical room temperatures this rock-solid state lasts for twenty-four to thirty-six hours, before advanced decomposition begins to loosen the muscle groups in the same order that they seized.

About the same time that Nysten was refining his rigor chart, English physician John Davey became the first to thrust Gabriel Fahrenheit's 1710 invention—the sealed-glass, mercury-column thermometer—into a human body at autopsy. With this instrument, the students of death had been given the means to add hatch marks to the algor mortis clock, previously little more than a marker for the half day it took a corpse to become cold to the touch. Unfortunately, Davey began his experiments, not in his



temperate homeland, but in the sweltering heat of Malta, the Mediterranean stronghold captured by the British in 1800. Consequently, the corpses of Davey's British soldiers actually rose as high as 108 to 113 degrees Fahrenheit in the hours after death. Nonetheless, Davey saw the implications—that the gradual equilibration of a body's temperature with that of its surroundings could be used to estimate time elapsed since death. Years later, he would become the first person to mention the forensic potential of cadaver temperature in his 1839 textbook *Researches, Physiological and Anatomical.*

Davey's widely read book prompted various pathologists to attempt their own algor mortis measurements. Unfortunately, the pathologists Davey so inspired failed to heed his wisdom in placing his thermometer *inside* the body. Temperature readings on the skin, typically in the armpit, resulted in what would become the near unshakeable dogma that body temperature dropped at a precise and steady rate of 1.6 degrees an hour (soon rounded to 1.5 for ease of calculation). Greatly popularizing this belief, in 1887 Frederick Womack published his to-the-minute, time-of-death calculations on 118 cadavers. Womack performed his temperature calculations in the mortuary and Anatomy Theatre of London's St. Bartholomew's Hospital, allegedly without being told the actual time of death recorded on each patient's death certificate. In the preamble to his first case, he apologizes for his "gross" error of estimating the patient's time of death at 4:54 P.M., when in fact the attending physician had recorded it as 5:05 P.M. Today, we know Womack's accuracy to have been impossible, given his or any other known method of estimating postmortem interval. Nevertheless, his reports solidified nineteenth-century beliefs in the pinpoint accuracy of algor mortis.

Together, the triple stopwatches of rigor, livor, and algor gave nineteenth-century pathologists the confidence to estimate time of death over the first twenty-four to forty-eight hours, up to the point where lividity became fixed, bodies reached room temperature, and rigor melted away. To expand their timetables into the long term, they turned to the scientific records of the previous century.

* * *

THE PIONEERING WORK of Europe's eighteenth-century anatomists led to the popular image of grave-robbing mad scientists, portrayed in Mary Shelly's *Frankenstein* and Charles Dickens's *A Tale of Two Cities.* It was no secret that many of the Continent's most eminent physicians participated in body snatching or employed their own "resurrection men" to supply their schools. Just how long these death-hardened scientists dared to study their rank cadavers before disposing of them remains unclear. We know they were familiar with the red, green, and black palette of bacterial growth that creeps across the body in the days and weeks after death. This *putrefaction*—the next important marker on the postmortem time line—brings an end to both rigor and lividity by turning muscle to mush and hiding lividity beneath a darker, broader stain.

The first outward sign appears as a subtle flush of green over the right lower abdomen, usually some twenty-four to forty-eight hours after death. Accompanying this emerald bloom is bloat, the postmortem distension that, in 1669, Sir Francis Bacon described as the work of "unquiet Spirits" fighting to break free of the mortal remains. Not until the 1860s would the "father of microbiology," Louis Pasteur, refute the "occult powers" and "internal agitation" of Bacon's unquiet spirits and identify the real culprits behind the bloat and stain of human decay. Though better known for his identification and eradication of food-spoiling germs, Pasteur sang the praises of the "moulds, mucors, and bacteria" that he claimed "combusted" the human body after death. Without them, he wrote, "life would become impossible because the restoration of all that which has ceased to live, back to the atmosphere and to the mineral kingdom, would be all of a sudden suspended." In other words, we'd all be knee-deep in carcasses.



Though Pasteur erred in assuming that the bacteria of decay required oxygen to "combust" the body (most, in fact, operate anaerobically), he set the course for later microbiologists to track the rate and direction of the bacterial growth in the hours, days, and weeks after death. Ground zero turned out to be the *cecum,* a cozy anatomical pouch at the head of the large intestine. During life, the body's normal bacterial fauna content themselves inside the cecum's warm puddle of liquid feces, with any overgrowth quickly beaten back by the patrolling white cells of the immune system. But once death garrotes their jailers, the cecum's bacteria multiply exponentially. Typically, their booming population breaks through the intestinal wall two to three days later. Spilling into the abdomen, they drift into the now passive circulation system, following its stagnant streams up the chest, down the limbs, and across the face.

The gases produced by the traveling bacteria mix and react with the deoxygenated blood to marble the body in shades of green and black along the feathery tracks of superficial vessels. At first, the delicate marbling remains confined to areas of livor mortis. By the fourth or fifth day, it tends to broaden into a black smear that shadows first the face, then torso and limbs.

Meanwhile, bacterial gases have inflated the trunk grotesquely. Tongue and eyes protrude. Lips swell and curl in an exaggerated pout. Breasts and genitals balloon to obscene proportions. Hair loosens and can now be pulled out in shanks. The internal pressure also forces bloodstained fluid from the mouth and nose—the benchmark purging described by Sung Tz'u in 1247.

It is at this stage that the once-smelled, never-forgotten odor of death permeates entire buildings and neighborhoods, making even the best-hidden corpse impossible to ignore. German chemists of the 1800s identified the pungent gases as the sulfur-rich waste products of protein-gobbling bacteria. Recognizing a new class of biochemical, they dubbed them *ptomaines*. Among the most prominent: the aptly named *putrescine* and *cadaverine*. The intensity of their repulsive odors—building, peaking, and subsiding in the weeks after death—provides its own strange clockwork.

Nineteenth-century anatomists were meanwhile documenting the "Swiss cheese" pattern of tissue destruction caused by the bubbling of bacterial gases through the liver and brain. Percolating to the skin's surface, these putrid gases likewise draw body fluids into dusky-colored blisters that loosen and lift the skin. Sometime between day three and the end of the first postmortem week, the loosened skin readily slips from fingers, hands, and limbs like fine-mesh stockings.

From such gruesome observation came forensic pathology's earliest textbooks, as well as the first institutes of legal medicine, established at universities in Leipzig, Paris, Lyons, Edinburgh, Glasgow, and London in the early to mid-1800s. At such centers, pioneers in the new field could carry out their research in close proximity to Europe's greatest detective forces, including those of Scotland Yard and the Paris Metropolitan Police.

Such collaboration between the worlds of medicine and forensics took longer to take hold in North America, where the politicized English coroner system, introduced in colonial times, still held sway. The situation would change with the sensational murder that shook Boston society just before the Christmas holidays of 1849. Fortuitously, both victim and prime suspect were intimately connected with Harvard Medical College, the former as a major benefactor, the latter a professor of chemistry. As such, both were friends with the country's leading anatomists of the day—medical men who volunteered their services in the murder trial that followed.

The story of Dr. George Parkman's murder has been retold many times in many ways, in literature, drama, and annals of the American legal system. In essence, the Boston socialite and philanthropist disappeared on the morning of his appointment with the quick-tempered professor of chemistry John Webster, a social climber known to live beyond his means. Also well known was the subject of the meeting: the long-simmering dispute over Webster having first borrowed money from Parkman and then duplicitously offering the agreed-upon collateral (a valuable gem collection) as security for a subsequent loan from another man.



When questioned after Parkman's disappearance, Webster presented a note apparently initialed by the doctor to acknowledge the loan's repayment that day. The two parted on good terms, Webster claimed. Support for Webster's version of events appeared in the form of witnesses who said they recalled seeing Parkman in town that afternoon. Police began to look for a common criminal who might have waylaid the doctor for the money.

Meanwhile, Webster's furtive doings inside his locked laboratory on the days following Parkman's disappearance raised the suspicions of the college's watchful janitor. In the middle of the night, the janitor broke through a basement wall to a pit beneath the laboratory's private toilet (little more than an indoor outhouse). There he found the decomposing remains of a partial torso, a thigh, and a shank of leg. Called to the scene, the city marshal ordered Webster's laboratory searched. In the furnace, the police found the charred remains of human bones, including a jaw.

In the sensational murder trial that followed, prosecutors faced the huge task of proving murder in the absence of a clearly identifiable body. Indeed, the case set legal precedent as to whether such a conviction was possible sans corpus delicti. By most popular accounts, the identification of the remains centered on the testimony of Parkman's dentist, who produced a denture mold that perfectly fit the charred jawbone handed to him by the prosecutor. The courtroom demonstration appeared even more compelling alongside a sketch of Parkman's profile with its distinctively protruding chin.

In reality, Webster's defense lawyers refuted the supposedly "perfect" match by calling their own dentist to the stand, a well-known denture maker who showed that the jawbone fit equally well in a half dozen dental molds from other patients. It remained unproven whether the jaw found in Webster's laboratory furnace was that of the murdered Parkman, or the leavings of some long-ago anatomy experiment. In fact, Webster's chemistry laboratory adjoined a dissection vault filled to the rafters with unidentified bones.

More damning was the testimony of the Harvard anatomists assigned to the prosecution's "postmortem committee." In his historic account of the trial, Simon Schama writes of Dr. Winslow Lewis's testimony on the state of the remains found in the laboratory privy:

> Though forensic, his language was quite different from the severe monotonies of the law; it explored and reported from the anatomy unsentimentally but with a kind of sensuous exactness, a poetic attention to hue, that riveted the attention: ". . . from left scapula to right lumbar region, of a dark mahogany color and hardened . . . a little greenness under the right axilla, probably from commencing decomposition, and some blueness under the left axilla—leaving the skin soft and easily broken . . . "

Dr. Lewis's unshakeable conclusion: When discovered by the college janitor, the remains in the privy pit had reached a state of decomposition consistent with death on the day of Parkman's disappearance. The jury found Webster guilty of murder, and he hanged.

The impact of the case and its grotesque medical testimony could hardly be underestimated. Warranted or not, the apparent precision of the expert's findings created an image of the doctor as infallible murder witness. Over the next twenty-five years, the United States moved rapidly to integrate medical experts into its



antiquated coroner system, with one state after another amending its laws to authorize coroners to employ physicians to assist in their investigation of homicides and suicides. In 1887, Massachusetts took the next step, appointing the first state medical examiner, with supreme authority over "all dead bodies of such persons as are supposed to have come to their death by violence." The crime-ridden cities of Baltimore and New York followed suit, opening their own busy medical examiner offices in 1890 and 1915.

More important, interest in forensics was growing in academia, particularly at Harvard, where medical men continued to debate the sensational testimony of the Parkman murder. In 1937, the school established America's first program in "legal medicine" as a subspecialty of pathology, the postmortem study of disease. With the lavish support of the early Rockefeller Foundation, the residency-type training program became a greenhouse for the cross-fertilization of medicine and criminology, exposing the nation's most promising young pathologists to the expertise of its leading homicide investigators as well as world authorities in human anatomy and physiology.

Most promising of all was the opportunity for new research. At last, modern science seemed poised to transform the crude postmortem sandglasses discovered by the ancients into the precise medical chronometers needed to nail death to the hour, if not the minute. As the eager young bucks of pathology focused their microscopes and honed their histological assays on the tissues, fluids, and breakdown products of the dead, the message went out: Murderers beware.

With cruel irony, the next fifty years of research would instead reveal pathology's own version of Heisenberg's uncertainty principle. Though many scholars were loath to admit it, the closer researchers looked at the biological signposts of death, the muddier their markers appeared. Instead of sharpening the time-of-death determinations made by earlier pundits, their findings made any claim to accuracy look hopelessly naive.