The Deadly History and Apocalyptic Future of Lethal Gases That Threaten Our World

SCOTT CHRISTIANSON

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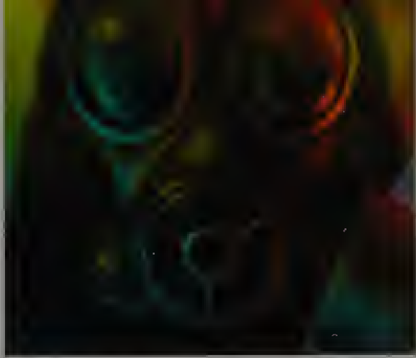

FATAL AIRS

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Lethal natural gases, including carbon dioxide, sulfur dioxide, hydrogen sulfide, carbon monoxide, methane, and radon, have been implicated in mass extinctions and local deaths throughout Earth's history. Today, a Pandora's box of human-made gases is circulating in our air, doing insidious damage to human beings and the environment—threatening us with potential catastrophic damage.

Fatal Airs: The Deadly History and Apocalyptic Future of Lethal Gases That Threaten Our World relates the fascinating—and appalling—stories of the discovery, development, applications, and occupational and public health hazards of natural and human-made gases. Some of these gases have figured in mass extinctions. Others have created havoc through their use in chemical warfare or their accidental release.

Among the hundreds of human-made lethal gases, several have been singled out for attention, including chlorine, phosgene,

(continued on back flap)

Fatal Airs

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For the sibs: Susie, Peter, and Carol, and in memory of Mom

. . . They strike
Their alter'd lyres, incensed, to fatal airs,
And measures fraught with sad calamity . . .

—Claudian, *The Rape of Proserpine*,
trans. Jacob George Strutt (1814)

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Preface

For tens of thousands of years of life on Earth, human beings took for granted the air they breathed; in some cultures their sages actually regarded it as nothing—something invisible, indivisible, even nonexistent. A number of ancient civilizations accorded noxious fumes from volcanos and other sources a special status, incorporating gases into their creation myths and cosmology. Yet scientific understandings of the nature, applications, byproducts and consequences of the substances documented in this book are of very recent vintage.

The very notion of gas was not invented until the mid-seventeenth century when a Flemish physician-chemist coined the term from the Greek χάος ("chaos") to describe the harsh vapors given off from burning wood. Scientists did not begin to systematically study gases until the eighteenth century. Joseph Priestley is generally credited as having discovered oxygen in 1776 as part of his effort to separate the gases in air. The identification and exploration of lethal gases only started in the nineteenth century.

The start of the Industrial Revolution introduced a new element into the equation that would dramatically change the world. Factories, engines, and the development of new carbon-burning fuels not only revolutionized human societies, they also altered the environment.

In the twentieth century, state-sponsored warfare researchers suddenly conjured up an astonishing array of gaseous concoctions that were designed and manufactured in massive quantities for no other reason than to kill other human beings. As this book shows, the First World War ushered in an arms race in the development of weapons of mass destruction that dwarfed anything that had occurred up to that point. Although the use of "asphyxiating or deleterious gases" was prohibited under international standards of law and morality, chemical weapons were first unleashed on a large scale in France and on the Eastern Front beginning in 1915. The results were horrific. Within just three or four decades, some of the world's major powers had used their new gas weapons to slaughter millions of persons in battlefields and prisons, all the while considering it "a higher form of killing."

The makers of poison gases also devised innumerable ways to put their creations to "constructive peacetime uses"—ostensibly to eradicate pests, fight disease, harden steel, separate ores and perform countless other functions. Invariably, however, they did this without regard to the collateral damage they might inflict on animals, water, air and vegetation. From time to time, such industrial uses have inadvertently resulted in chemical explosions and accidental poisonings, or spawned major disasters such as Bhopal, but that has not deterred the chemical companies either.

This book examines the deadly history and possibly apocalyptic future of lethal gases. It also implicates them in some key social problems: the dangers of chemical weapons employed by states and terrorists, the rampant assault of industrial poisons on human health and the environment, and the potential role of gases in extinguishing life on the planet, to name a few. At a time when gas-driven global warming and climate instability are fast approaching a tipping point, it is certainly a story that underscores the power of the forces of Nature and reminds us once again that humans' efforts to shape their environment often carry baleful, unintended consequences.

The World Health Organization estimates that about two million people die prematurely every year due to air pollution, while many more suffer from respiratory ailments, heart disease, lung infections and cancer, much of it caused by microscopic particles from industrial activity and other sources of combustion. Emissions of sulfur dioxide and other deleterious gases have been curtailed in some areas, due to better anti-pollution controls; however, they are increasing in other developing nations such as China and India, and others may not be far behind.

Today there continue to be mounting dangers posed by intentional or accidental discharge of man-made lethal gases, and scientists are becoming increasingly aware of the role of greenhouse gases in causing or contributing to a number of extinctions on earth as well as threatening future havoc from global warming accelerated by unfettered human activity. Nevertheless, societies have shown themselves to be ill-prepared to deal with the consequences of larger-scale lethal gas disasters, and the world community as a whole has not sufficiently mobilized to seek prevention of such catastrophes.

This book traces some of this elusive and neglected gaseous history, exploring a few of the memorable characters, exciting discoveries, chilling results, and fearsome possibilities that have made up the record of humankind's fatal airs. Moving from ancient temples to modern scientific laboratories, it seeks to probe several lethal gases in particular with a sense of wonder, cataloguing their strange evolution and peculiar qualities, and putting them all in fresh post-industrial perspective.

The narrative follows the development and effects of such war gases as chlorine, chloropicrin, mustard gas, phosgene, lewisite, sarin, tabun, and V-agents; recounts the deadly abuses of hydrogen cyanide; examines the silent killer, carbon monoxide; and uncovers the hidden dangers of radon. The story of their discovery, exploration and development constitutes one of our riskier attempts to harness deadly chemicals for all sorts of purposes, both good and bad. Much of the book involves what humans do with lethal gases. The book also examines the vital importance of several greenhouse gases, particularly carbon dioxide, methane, and nitrous oxide, to name a few.

While the scientific study of deadly gases is relatively new and filled with accidents, missteps, recklessness and naiveté, one would think that human beings would already have learned enough to make them wary and mindful of the dangerous, unpredictable, and chaotic nature of these strange and mysterious substances. But that has not always been the case. Some of the early gas explorers were daredevils; their ability to see potential uses in such mysterious substances also sets them apart as visionaries. Nowadays, pioneers employ satellites, ground-penetrating radar and other space-age technology to explore the otherwise invisible or unfathomable world of gases.

Each lethal gas poses its own unique dangers; combined in various ways, they may form a lethal brew that could prove even more difficult to sort out and control.

Lethal gases are not yet on a global rampage, but they are more ubiquitous than many people realize, and their potential for mischief is greater and more pressing than most probably imagine. Today we stand at the threshold of a new era in which organized society will increasingly have to try to understand and tame them before it is too late. But that may not be possible: their destructive powers could prove beyond human control. The struggle with these lethal airs has only just begun. It is a war we cannot afford to lose.

I suppose my interest in the subject dates back to my boyhood in the 1950s when I spent endless hours gazing up at the clouded sky and the memorable occasion when my great-uncle Philo Dutton showed me his timeworn gas mask and helmet from World War I and recollected some of his vivid memories of the horrors of chemical warfare. In recent years, my concerns about weapons of mass destruction, terrorism, the death penalty, and threats to the environment coalesced to prompt me to dig deeper into the role that gases have played in each of these vexing problems.

Some of those who provided information and assistance to me in my study of lethal gases included Commander Jack Alderson of Operation SHAD/112; Mike Bailey, a veteran of Edgewood chemical warfare human experimentation tests; Ryan Bodanyi, of Students for Bhopal; Mike Bonanno, of The Yes Men; Gary Cohen of Environmental Health Fund; Rick Engler of the New Jersey Work Environment Council; Prof. Kim Fortun and Judith Frangos of Rensselaer Polytechnic Institute; Aquene Freechild, of the Environmental Health Fund; Rick Hind, legislative director of Greenpeace; Dr. Daniel M. Horowitz, of the U.S. Chemical Safety & Hazard Investigation Board; Peter Johnston, founder of the Carbon Monoxide Survivors Association International; James S. Ketchum, MD, former researcher at Edgewood Arsenal and author of *Chemical Warfare Secrets Almost Forgotten*; Michael Laurence, director of the Habeas Corpus Resource Center, San Francisco; Sanford J. Lewis of the Good Neighbor Project; Ward Morehouse, activist and author; Prof. Michael Radelet, University of Colorado; Ted Smith of San Jose, an expert on Silicon Valley toxics; Frederica Valois of Woods Hole Oceanographic Institute; and Craig Williams, Chemical Weapons Working Group. I appreciate their help. To others who wished to remain anonymous, thank you as well.

My research was also facilitated by archivists and librarians at the National Archives, Hagley Museum and Library, Rensselaer Polytechnic Institute, State University of New York at Albany, and many other august institutions. It was also fueled by countless gallons of coffee from Roasters Whim.

During the book's final stages of writing, I had the good fortune to work with Egmont R. Koch of Bremen, Germany, one of Europe's finest investigative journalists and filmmakers, on a documentary film about the cyanide cartel involving IG Farben, E. I. duPont de Nemours & Co., and other chemical industry giants that manufactured poison gases and other weapons of destruction in World War II. Commissioned by the Arte and WDR television networks, we combed the United States and the United Kingdom, Germany, Switzerland and Poland in search of archival materials, locations and experts that would shed light on the evolution of the gas chamber that claimed millions of prisoners' lives. Our travels took me to the Nevada State Prison in Carson City, where the world's first gassing execution was carried out on February 8, 1924, and I stood among the sagebrush at Gee Jon's unmarked desert graveside and tracked down the chair in which he and other early gassing victims had been strapped. During a violent thunderstorm we also shot pictures inside a patented steel-and-glass gas chamber device in Cañon City, Colorado, that had been used to asphyxiate convicts at the Colorado State Prison. Our quest to trace the development of lethal gassings in Nazi Germany ultimately brought us to Oswiecim, Poland, where we toured the former Auschwitz-Birkenau concentration camp, witnessing first-hand the machinery of death involving Zyklon-B. I shall never forget what I saw there.

A number of editors in the publishing world were instrumental in helping me to get this history of lethal gases into print. They include Philip Turner and Iris Blasi, who initially suggested to me the topic of this book. Robert Hutchinson of Praeger provided unflagging encouragement, support, and literary acumen as I completed the manuscript. R. Bhuvaneswari of PreMedia Global oversaw the book's production with Bridget M. Austiguy-Preschel of ABC-CLIO and Carol Ann Ellis served as the eagle-eyed copy editor. I accept full responsibility for any errors and imperfections.

As always, several relatives and friends proved vital in the making of this book. They include my father Keith R. Christianson, Myron and Jetta Gordon, Kelly and Scott Whitney, Emily Christianson, Michael Gardner and Eve

Gordon, Kenny Umina, Richard Jacoby, Ralph Blumenthal, David Hess, Steve Pierce, Igor Vamos, Egmont R. Koch, and of course, my beloved wife and partner, Tamar Gordon. She and our son Jonah put up with me when I was off in the clouds. Maybe now that this one is done we will have some room to breathe.

Fox Manor
March 2010

Chapter 1

Agents of the Gods

On the southern flank of Mount Parnassus in Greece rise two great limestone cliffs cut by a chasm. In ancient times, records the classical historian Diodorus Siculus, a goatherd tending his flock at the foot of the cliffs noticed that some of his goats were behaving strangely. The ones browsing on the edge of the wild chasm were capering about and bleating weirdly. Approaching the edge of the chasm, he found himself behaving like his goats, except that instead of bleating he was uttering odd prophesies. Soon the word spread among the people of the vicinity, and others flocked to test the powers of the site and they too found it oddly inspiring. "For these reasons," according to Diodorus, "the oracle came to be regarded as a marvel and to be considered the prophecy-giving shrine of Earth."[1]

At that peculiar spot, crisscrossed with faults and cracks carrying warm springs through the limestone rock, the ancient Greeks built a temple atop one of the springs and developed elaborate rituals around what they called the Oracle at Delphi. Under this arrangement, a female cult agent known as the Pythia sat on a special bronze tripod, breathing gas from the spring. The believers held that a "divine afflatus" sent her into a trance in which she uttered mystical observations to a male prophet, who translated them into oracular pronouncements that were said to come from the god Apollo.[2]

The ancient Greeks and Romans considered Delphi the *omphalos* or center of the world. Modern scholars have concluded that the place functioned as a sacred site from about 1400 BCE to 381 CE. For much of that time, a series of religious ceremonies were carried out there. On the morning of a scheduled Oracle prophecy, a live goat would be brought to an altar just outside of the great Temple of Apollo. A priest would then perform the sacrifice and examine its warm, bloody entrails to determine if the oracle would operate that day.[3]

Tradition prescribed that a woman of distinctive qualities be selected from the peasantry to serve as the Pythia, until she had to be replaced (perhaps because she had suffered ill effects from the gas emitted from the cavern). Each of these priestesses of Apollo was expected to complete a prescribed ritual: in a specially designed chamber, she would be purified in the holy waters and dressed in full ceremonial robes, often as she chewed special laurel leaves. Then she would be escorted into the temple where she would seat herself on the tripod, from which she would inhale the potent holy vapors emanating from the earth.

Before any pilgrim could enter Delphi's temple and descend into the smoke-shrouded enclosure, he was required to make an offering. Then his question would be written down and presented to one of the oracle's assistants. The pilgrim had to wait in a corner until an assistant recorded the answer and delivered it back—a process that could take many minutes or countless hours.

According to the myth, the god Apollo spoke through the female oracle, expressing his wishes and advice through the oracle's human voice. But the channeled message could often prove perplexing to interpret; the Pythia's erratic behavior and intoxicated manner of speaking, wild cries and gesticulations frequently led to misunderstandings of her meaning. From time to time each woman serving as the Pythia was suddenly replaced, leaving historians to wonder what ever happened to them: were they overcome by the gas or sacrificed? And what were the strange vapors?

Pilgrims came from all over Greece and distant lands to offer their pressing questions to the Pythia, and her rambling or cryptic answers could determine the course of everything from mundane matters such as when a farmer should plant his seedlings to earthshaking affairs of state such as whether an empire must declare war. Intermediaries often argued over a prophecy's true meaning, and if necessary the oracle would always give another prophecy in exchange for more gold—as, for example, just before the crucial naval Battle of Salamis in 480 BCE when the Pythia initially predicted that Persian invaders would overwhelm the Athenians. But later, after additional payment, she refined her prophecy to say that a "wooden wall" would save them. In that case, the Athenians interpreted the prophecy to mean the Oracle was referring to their wooden ships, and this was subsequently proved correct when they defeated King Xerxes at sea.[4]

Over the centuries, the Oracle at Delphi helped to shape the course of ancient Greco-Roman civilization. Plutarch, the philosopher and writer, served as a priest of Apollo, interpreting the divine predictions. The great mathematical thinker Pythagoras went there and trained a Pythia to serve as the voice of the god. Herodotus, the historian, came to chronicle what was prophesied. Delphi was where the great lawgiver Solon sought instructions for creating laws that would make Athens a model city-state. And Alexander the Great pressed the oracle for a pronouncement that he would be invincible.[5]

Sometimes the prophecy of the vapor-breathing oracle was clear. When Orestes appealed for guidance about whether he should murder his mother for killing his father, the Pythia clearly appeared to approve his matricide, setting in motion a tragedy that was later played out in many classic myths. But when the oracle predicted to Oedipus that he would slay his father and defile his mother, Oedipus fled from them in horror, not realizing that they were his adoptive parents, only to unwittingly fulfill the prophecy later with his biological parents, Laius, the King of Thebes and Jocasta, his wife. After the truth became known, Jocasta took her own life, and Oedipus put out his own eyes and roamed the earth in eternal misery.[6]

After its heyday in about 800 BCE, however, Delphi's stature gradually diminished, and the oracles became more and more infrequent because, it was said, Apollo was removing his presence. Finally, in the fourth century CE, Rome's Christian emperor Theodosius decreed all pagan temples closed and forbade any further oracles. When the pagan Emperor, Julian the Apostate, inquired how he could help restore the Pythia to power, Apollo was said to have replied: "Tell the emperor that my hall has fallen to the ground . . . [Apollo] no longer has his house . . . nor his prophetic spring; the water has dried up."[7]

Theories about the mysteries of the oracle divided many modern scholars. In 1904 an excavation by French archaeologists further fueled the controversy when it found no evidence of any gas at Delphi, prompting many modern-day experts to dismiss the gas mythology as fantasy and fraud. But in 2001 a group of American scientists reported they had found two major intersecting faults in the ground directly below the Delphic temple. The interdisciplinary archaeological team led by John Hale of the University of Louisville and geologist Jelle Zeilinga de Boer of Wesleyan University revealed they had detected traces of three hydrocarbon gases that had risen from the spring and been preserved in the temple rock. Their analysis concluded that at least one of the gases was hallucinogenic. Specifically, they cited the presence of ethylene (ethane), which is known to create euphoria and other psychological effects, as well as nausea, hyperglycemia, changes in blood pressure, hypoxia, loss of consciousness, and death, depending on the level of exposure. The researchers noted that the Delphi fault system is located at the center of the Corinth Rift Zone, one of the Mediterranean's most active seismic areas. They pointed out that heat deep in the rift zone drives fluids rich in dissolved hydrocarbon gases to circulate upward through the fault system. As the fluids approach the surface at Delphi, they emerge as springs and vent a fraction of their hydrocarbon gas bubbles as volatile fumes. Extrapolating such present phenomena to the recent geologic past in ancient Greece, the Wesleyan researchers inferred there is a correlation between the presence of mind-altering gases in the natural environment of the temple today and the outlandish features of the Dephic cult reported in the ancient literature.[8]

Delphi was not the only ancient place in which gases held sacred significance. The city of Hierapolis, a former Grecian sacred site in southwestern Turkey that had been founded more than two millennia ago and later ceded to Rome in 133 BCE, lies amid magnificent white cliffs and terraces overlooking the Menderes River. The Turks renamed it Pamukkale ("cotton castle") for its distinctive appearance. Scientists later discovered its unusual appearance was caused when water from the subterranean hot springs flowed down the slopes, leaving heavy deposits of white calcium carbonate. Excavations have been going on there since the late nineteenth century, revealing an elaborate ancient complex of gleaming marble temples. Archaeologists have found a large necropolis filled with sarcophagi, a theatre, and a gymnasium. Immense marble baths were built over the bubbling hot springs in the belief that the waters possessed miraculous healing powers. Inscriptions on many of the local tombs reflect the presence long ago of a large Jewish population and the sufferings of Christian martyrs before an earthquake destroyed the city. Today it is a popular tourist attraction.[9]

Stories about Hierapolis were the stuff of Greek mythology and accounts by ancient historians. A century after Christ's birth, Strabo described a cavernous gas chamber located near the temple. Known as the *plutonion*, it was apparently used to carry out sacrifices to the god of the underworld. On the south side of the temple was an arched entrance to the grotto known as the Place of Evil Spirits. According to Strabo, only the Eunuchs of Cybele were "immune to the extent that they can approach the orifice and look in, and even penetrate for some distance, though not necessarily without holding their breath." Others later theorized that the eunuchs had probably covered their heads with multiple cloth sacks in order to create a pocket of air. Another possibility is that they had trained themselves to hold their breath long enough to survive for a few minutes as they crawled amid the poison gas inside the deadly *plutonion*, thus creating the false impression that they possessed some sort of magical powers. But scholars have questioned whether the legends had any basis in fact.

In 2006 a team of Italian archaeologists from the University of Lecce-Via Arnesano, using the latest state-of-the-art technology, reported making a series of stunning discoveries at the site. Ground-penetrating radar and electrical resistivity topography enabled them to locate and measure possible underground structures, in order to explore a previously buried area beneath the temple.

Approximately 8 to 14 feet down, the researchers found a man-made tunnel leading to a small room that appeared to have been a structure where victims were prepared for sacrifice. From that space the tunnel continued to a hole nearly 30 feet wide which they identified as the *plutonion*. The hole still emitted a thick mist of sharp-smelling carbon dioxide that made it impossible to see inside, and the remains of dead animals littered about attested to its lethal power.

The researchers concluded there was physical evidence consistent with several parts of the mythical accounts, in that priests had indeed retrieved sacrifices from the smoky pit, prepared them in a special underground room, and displayed the results in the temple as part of an elaborate religious ritual. Ancient audiences might well have concluded that some sort of supernatural intervention had taken place, therefore believing that the priests were infused with superior powers and had divine protection. The new findings suggested that the *plutonion* may have served as a death chamber more than 2,000 years ago, and thus may represent the earliest known execution gas chamber in human history.[10]

The cults at Delphi and Hierapolis ascribed divine powers to the inhalation of certain natural vapors, and such inhalations would also play an important role in other societies' religious practices through the ages. Worshippers in the ancient Babylonian and Judaic worlds breathed vapors from burnt spices. Native Americans smoked tobacco, and tribes in some African and South American Indian civilizations associated magic powers with certain mind-altering gases. Cannabis was used in ancient China, India, Nepal, and the Middle East. Gas-producing volcanoes figured in the myths of many ancient cultures. Hephaestus, the Greek god of fire and the son of Zeus and Hera, was said to use a volcano as his forge. Vulcan, the Roman god of fire, followed in the same tradition, using his forge to fashion metal weapons for Mars, the god of war; ancient Hawaiian myths told that the islands' earthquakes, gas clouds, eruptions and lava flows were caused by Pele, the tempestuous goddess of volcanoes. Early civilizations also began to use gases in combat. "Greek fire," for instance, an early secret weapon of the Roman emperors, was said to have been invented by Callinicus, a Jewish architect from Heliopolis, in the seventh century. This "liquid fire" was hurled onto enemies' wooden ships and burst into flames on contact, even on water, causing extreme panic and dread.[11]

Chapter 2

Plucky Pioneers

The human struggle to grasp the strange properties of natural and man-made gases, lethal and otherwise, gradually evolved over thousands of years. But primitive notions about poisonous spirits and vapors wielded by the gods held sway until relatively recently in history, long after people had tried to harness such power in art, cooking, medicine, and war.

As ancient civilizations introduced various metals, their efforts in metallurgy came to involve intense and repetitive work with fire, melting and separating impurities from the ores, smelting and other processes that often exposed workers to extreme heat, smoke and vapors. Ancient societies also labored to produce pigments and dyes, glass and glaze, and to tan leather and create other distinctive objects. Still there was no science of chemistry or any real scientific understanding of gases.[1]

Beginning about 335 BCE, a hybrid culture of Greek and Persian influences came together to create a new sort of "philosophic technology," known as alchemy. It did not resemble today's chemistry very much, although it was an early version of that science. Part sorcery and part astrology, alchemy in its broadest sense sought to understand the universe; its practitioners believed there was something elemental or intrinsic preserved even in the most dramatic changes of physical state and appearance. Organized as the study of transmutation, alchemy's primary dictum in Latin was *Solve et Coagula* ("Separate and Join Together"), and much of the driving impetus for its importance lay in its preoccupation with gold; sometimes these efforts to create gold and other precious metals from other materials promoted a tendency toward fraud and trickery. In the fifteenth or sixteenth century, however, alchemists such as Theophrastus Bombastus von Hohenheim (Paracelsus) began to seriously apply their knowledge to the service of medicine. Paracelsus gained some of his renown based on his success at achieving cures by employing opium and preparations of mercury.[2]

Despite its checkered past, alchemy, or traditional chemical philosophy, gradually evolved as the forerunner of chemistry, which is generally defined as the science of the composition, structure, properties and reactions of matter, especially of atomic and molecular systems. This real transition from alchemy to chemistry began in the seventeenth century. Yet most of the early chemists were still alchemists at heart, who spent much of their time as pharmacists, preparing medicines, extracts and salts.[3] One of the most significant of these early chemists was the Flemish physician Johannes (Jan) Baptista van Helmont (1577–1644), a nobleman-scholar who had carefully studied Paracelsus and called himself *philosophus per ignem* (philosopher of fire). While Helmont still clung to some of the old superstitious remedies such as drawing worms from the eyes of toads, he was also quite advanced in a number of his medical practices, such as examining urine as a diagnostic tool. Indeed, his willingness to go his own way sometimes got him into trouble with the authorities. Because he lived in Belgium when it was possessed by Spain and subject to the Spanish Inquisition, one of his published remedies struck the ruling body as heresy, as a result of which he was subsequently put on trial and held under house arrest for two years. Nevertheless, he continued to break new ground.

Helmont was the first to realize that there are gaseous substances other than air. "Suppose thou, that of 62 pounds of Oaken coal, one pound of ashes is composed," he wrote. "Therefore the 61 remaining pounds are the wild spirit, which also being fired, cannot depart, the Vessel being shut." In one of his most famous passages, he continued, "I call this Spirit, unknown hitherto, by the new name of Gas, which can neither be contained by Vessels, nor reduced into a visible body, unless the seed being first extinguished."[4]

Writing in the early seventeenth century, Helmont appears to have coined the term "gas" after the Greek *kháos* meaning chaos or empty space, a fitting name for the disordered and volatile substance that had proved so elusive yet so powerful. He was credited as the first to differentiate between *vapors* (formed from the effect of heat on water, and which could condense to give water again on cooling) and *gases* (which he said were dry, airlike substances which could not be changed into liquid). "Gas," he wrote, "is composed of invisible atoms which can come together by intense cold and condense into minute liquid drops." Helmont was the first to accomplish the production of gas in various chemical processes as well as the first scientist who was able to differentiate among gases. Among the impressive array he identified were *gas silvestre*, a poisonous gas that would not support combustion, variously evolved by fermenting liquor, burning charcoal, and dissolving marble with acid (modern *carbon dioxide*); *gas pingue*, which is flammable gas given off by putrefaction and contained in the large intestine (modern *methane*); and many others. Helmont was so proud of his discoveries that he christened himself the "inventor of gas."[5]

Nevertheless, Helmont's term "gas" did not find wide acceptance in chemistry until the nineteenth century, and for a long time not much was done with his newly discovered gases. Most of his early successors preferred terms such as "artificial air" or "factitious air" or even "different kinds of air." Robert Boyle (1627–1691), an Irish physicist, became the first person to succeed in actually collecting some gases. Stephen Hales showed in 1727 that distinct gases, or "airs" as he called them, differed in color, smell, solubility in water, and inflammability, but at the time no great importance was attached to this observation.[6]

Then, about the time of the American Revolution, a nonconformist British clergyman and chemist, Joseph Priestley (1733–1804), focused sunlight on mercuric oxide to discover something he called *dephlogisticated air.* Priestley then had the brilliant idea to conduct a test to see if it would support life. He put a mouse into a glass vessel containing two ounce-measures of the air from *mercurius calcinatus.* "Had it been common air," he observed, "a full-grown mouse, as this was, would have lived in it about a quarter of an hour." But in this gas, Priestley wrote, "my mouse lived a full hour; and though it was taken out seemingly dead, it appeared to have been only exceedingly chilled; for, upon being held to the fire, it presently revived, and appeared not to have received any harm from the experiment." Afterward, he too enjoyed the pleasure of breathing it. The gas he had described was oxygen.[7]

Beginning with Helmont's "invention" of gas, the early gasologists' explorations produced discoveries as great as any geographical ones, taking humankind on a trip aimed at solving what William Shakespeare described as "the mystery of things, as if we were God's spies."[8] Like voyagers such as Columbus or Captain Cook, many of these early scientific explorers exposed themselves to intense privations, enormous discomforts, and extreme and sometimes fatal dangers, in the course of their work. "The chemists are a strange class of mortals who seek their pleasures among soot and flame, poisons and poverty," one of them (John Joachim Becher) confided, though he was moved to add, "yet among all these evils I seem to live so sweetly."[9]

The experience of another trail-blazing chemist in the fields of gases—Carl Wilhelm Scheele—famously illustrates this phenomenon, although at the time he considered himself a "phlogistonist." Born in 1742 in Western Pomerania, Sweden, as one of 11 children, Scheele received very little formal education and no training in science. But at age 14 he became apprenticed to an apothecary and he made the best of that opportunity. Working for the apothecary gave him access to a basic supply of chemicals and introduced him to the mixing and measuring of various substances. After completing his apprenticeship in 1765, Scheele moved on to occupy a series of pharmacy positions in Malmö, Stockholm and Uppsala, which enabled him to perform his own chemical experiments. His greatest interest was to study the effects of phlogiston (a hypothetical substance early chemists thought was a volatile constituent of all combustible substances released in flame as combustion) on gases.

Following the tradition of the alchemists, Scheele wrote, "It is the object and chief business of chemistry to skillfully separate substances into their constituents, to discover their properties, and to compound them in different ways."[10] Even under the best conditions, this would not have been an easy task. But in his deprived situation it was daunting indeed, as he had to contend with poverty, extreme cold, and unsafe laboratory practices, to name a few of his hardships.

Scheele's makeshift workshop extended along a long stone fireplace that was designed to include various furnaces, ovens and heating apparatuses. Its rough surfaces were crammed with crucibles, tubs, flasks, dishes, bottles, and many odd-looking instruments. Because he conducted his experiments without adequate ventilation or safeguards, he unwittingly exposed himself to many harmful chemicals, often smelling and tasting his concoctions as he recorded everything he could about their characteristics. "How difficult it is, however, to carry out such operations with the greatest accuracy," he said.[11] Yet he persevered.

In 1772 or so Scheele conducted a series of experiments that led him to offer astonishing conclusions about the air that creatures breathed. "Air," he wrote,

> is that fluid invisible substance which we continually breathe, which surrounds the whole surface of the Earth, is very elastic, and possesses weight. It is always filled with an astonishing quantity of all kinds of exhalations, which are so finely subdivided in it that they are scarcely visible even in the sun's rays. Water vapors always have the preponderance amongst these foreign particles. The air, however, is also mixed with another elastic substance resembling air, which differs from it in numerous properties.[12]

Independent of other leading chemists of his day, Scheele concluded that the atmosphere was composed of two gases, each of which he was able to isolate. One, which supported combustion, he called "fire air" (later identified as oxygen) and the other, which inhibited combustion, he called "vitiated air" (now known as carbon dioxide).

Scheele's discoveries revolutionized the scientific world as much as those of any figure in the history of chemistry, although he did not receive the credit he deserved until years later. In 1775 he was elected to the Royal Academy of Sciences and offered a prestigious position as superintendent of a pharmacy. Yet it was his love of experimenting that kept him going. "Oh, how happy I am!" he exclaimed. "No care for eating or drinking or dwelling, no care for my pharmaceutical business, for this is mere play to me. But to watch new phenomena, this is all my care, and how glad is the enquirer when discovery rewards his diligence; then his heart rejoices"[13]

Although Scheele had probably been the first to discover oxygen, by the time he published his results in 1777, Joseph Priestley had already gained credit for discovering the same gas (which he called "dephlogisticated air") in 1774, because the Englishman had been quicker to publish his results.

But it was another gas that probably brought about his demise. One gaseous combination in particular that caught Scheele's interest gave off a curious almond scent, which he made the mistake of sniffing along with mercury. He remained unaware until it was too late that the compound he had created, handled, smelled and tasted—Prussian blue (hydrogen cyanide)—was one of the most deadly substances ever devised. Scheele became an invalid at age 35. As his health drastically declined from the mysterious illness, the sickened Swede ascribed his fate to "the trouble of all apothecaries," and realizing that death was near, he married a local pharmacist's widow in order that she could inherit his equipment and findings. He died at age 43—a victim of his own insatiable curiosity.[14]

Little did he or Helmont or others among the early gas pioneers know that their path-breaking discoveries and concoctions of gases would ultimately help to uncover some of Nature's darkest secrets—the formulae of fatal airs. Nor could they conceive the uses to which some of those lethal gases would be put.

Chapter 3

Volcanoes: Carbon Dioxide, Sulfur Dioxide, Hydrogen Sulfide

In the summer of 79 CE, the area at the foot of Mount Vesuvius near Naples experienced a series of minor quakes that were common to that area. After one round of tremors on August 20, the local water springs suddenly dried up and many animals began to act skittish. The local inhabitants did not know what to make of such signs. Then, shortly after noon on August 24, the sleeping volcano in Vesuvius suddenly exploded with an enormous roar, sending a column of pumice, rock and ash rising 12 miles into the sky and blocking the sunlight. The wind from the northwest blew the debris a few miles away onto the communities of Pompeii, Herculaneum, Stabiae, and other sites to the southeast, where it rained down in a mixture of hot hailstones and dust. As darkness descended amid sounds of electrical discharges from atmospheric disturbances, hot cinders covered the streets and rooftops, and poured into the buildings through open doorways and windows. Throughout the day, stunned residents wandered through the darkness, trying to escape, many of them gasping for air and suffering various injuries from falling objects. The hard rain kept coming. At first, about eight feet of pumice stones fell on Pompeii, followed by a layer of about four and a half feet of white pumice, and then topped by several feet of denser gray pumice. Some villagers tied pillows to their heads as protection from the raining objects, which averaged about 1/3 of an inch in diameter. But eventually the crude roofs collapsed from the weight, crushing and trapping the inhabitants inside.[1]

Vulcanologists would later call this phenomenon of volcanic eruption a *Plinian* phase, after the Roman historian, Pliny the Younger (61–ca. 113 CE), who recorded the Vesuvius events in letters to his friend Tacitus based on first-hand accounts and his own observations from across the Bay of Naples. In his report, he described the fate of his uncle, Pliny the Elder, who had been relaxing with some books at Misenum when the "evil cloud" appeared, forcing him to flee to the shoreline. There he managed to take a drink of cold water two slaves had provided and survive, until the smell of sulfur arrived, whereupon he suddenly gagged and died—choked and poisoned, it would later be discovered, by the noxious sulfur dioxide gas.[2]

Such events would have been bad enough for the local inhabitants, but Vesuvius had more in store for them: to that point the survivors had only been in what Dante later called "the vestibule of Hell." The end came on the morning of August 25. At least it was mercifully instantaneous. A sudden surge brought a whirling, chaotic avalanche of burning toxic gas and dust. The cloud traveled at astonishing speeds often exceeding 100 kilometers per hour, immediately baking the area and everything in it. Any survivors sheltered in Herculaneum's waterfront chambers, who had so far escaped suffocation, were instantly incinerated in a blast of hot gases and ash that had risen to a temperature of 500 degrees centigrade or more. The end came so fast, in a fraction of a second, nobody had time to brace or suffer—his or her vital organs underwent thermically induced fulminant shock and they were left in natural postures looking as they had been at that precise moment. Later the rains entombed the stricken Herculaneum in volcanic mud. A number of similar surges roared toward Pompeii but were briefly impeded by the northern city wall until one blast finally rolled up over its top and incinerated all buildings in its path. Anyone still alive was baked by the hot air of the surge. Archaeologists later uncovered many remains lying with their limbs pulled in toward their body, forming what has been described as the "pugilistic attitude," due to the intense heat that had contracted their flexor muscles into a fighter's pose.[3]

Pliny the Younger witnessed some of this raging fire from his vantage point across the bay and was terrified that he was about to perish with the rest of the world. Finally, however, after a period of time had passed, the cloud gradually began to lift and he could finally make out some of his surroundings. "The sight that met our still terrified eyes was a changed world, buried in ash like snow," he wrote.[4]

Archaeologists using hydrocarbon dating recently found evidence that an earlier volcanic eruption in 3500 BCE had also devastated Pompeii, indicating that the one in 79 CE had not been the only such cataclysm. Researchers have also warned that it may not be the last. Two thousand years ago, the city's population was only about 20,000, but today more than 3 million people live within range of slumbering Vesuvius, and some of them have been known to quip, "We're dancing on the volcano."[5]

Mark Twain said Vesuvius was "a mere toy, a child's volcano, a soup-kettle" compared to Hawai'i's colossal Kilauea. While on a newspaper assignment to Polynesia as a young journalist in 1866, Twain approached the seething mountain one day to find "ragged fissures that discharged jets of sulfurous vapor into the air, hot from the molten ocean down in the bowels of the mountain." In 1840 Kilauea had sent a broad river of this fiery gush, five miles wide and two hundred feet deep, sweeping down to the sea, consuming everything in its path. In that earlier great eruption, Twain wrote, "The atmosphere was poisoned with sulfurous vapors and choked with falling ashes, pumice stones and cinders; countless columns of smoke rose up and blended together in a tumbled canopy that hid the heavens and glowed with a ruddy flush reflected from the fires below," giving off a red glare that could be seen at night from 100 miles at sea and "at a distance of 40 miles fine print could be read at midnight." Fish were killed for 20 miles and accompanying earthquakes shook the island, causing some loss of life and sending off a huge tidal wave that drowned many more people and left a trail of utter devastation.[6] (Once again, earthquake, volcano and tidal wave all seem to have gone together.)*

Today Kilauea towers more than 12,000 feet from the ocean floor to the water surface and 4,000 feet above sea level. It is one of the world's largest and most watched active volcanoes. The U.S. Geological Survey's Hawaiian Volcano Observatory, established in 1912, uses elaborate equipment to monitor its gas emissions, and its scientists constantly check and study the data.[7] Millions of tourists flock to the Big Island, some just to get up close to one of the world's wonders, which hikers can explore at their own peril. Some visitors complain about the island's eye-stinging air pollution, especially near the volcano, where the gases rise like steam from a city sidewalk vent. Health officials warn that the volcanic gases are toxic, but that has not deterred tourists such as me from roaming the brittle fields around the smoky caldera.

Radioactive elements deep within the Earth are constantly disintegrating and producing intense heat that seeks to escape as the volatile gases boil and expand. A volcanic event occurs when magma movement causes a sudden, continuing release of energy. Magma (the molten matter gathering beneath the Earth's crust) is a fiery, fluid substance composed of silicates mixed with oxygen and other chemical elements. Its temperatures usually range from 700°C to 1300°C, although readings as high as 1600°C have been recorded. Magma exists at the high pressures existing deep beneath the earth's surface, generating hot gases. As magma rises toward the surface, various gases form tiny bubbles that escape through vents (fumaroles) in the Earth. When magma mixes with water, the gases undergo a tremendous expansion, sometimes resulting in explosive eruptions. Environmental scientists have only lately begun to study the composition and nature of these gases. Water vapor, carbon dioxide, and sulfur dioxide are the main gases released. Volcanoes also discharge hydrogen sulfide, hydrogen, carbon monoxide, hydrogen chloride, hydrogen fluoride, and helium. Huge quantities of these gases enter the atmosphere, leading to air pollution and contributing to global warming. The ones that pose the greatest health hazard are sulfur dioxide, carbon dioxide, and hydrogen fluoride.[8]

Sulfur gas is mentioned in the Bible and associated with Hell and brimstone. In reality, sulfur dioxide is a colorless gas, about 2½ times as heavy as air. It has a faint sweetish odor at low concentrations, although one of its more demonic

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*Earthquakes occur in the Earth's upper mantle or crust, which ranges anywhere from the surface to as deep as 500 miles, and they release a stupendous amount of energy. Gases often escape from the ground before, during or after an earthquake. But less is known about these phenomena than about volcanic gases.

characteristics is that at higher concentrations it loses its smell but becomes even more deadly. Health officials warn that a small dose of this gas can irritate the skin and the tissues and mucous membranes of the eyes, nose, and throat; higher levels can attack the upper respiratory tract and bronchi, possibly resulting in serious injury or even death.[9]

Pollution from sulfur dioxide reacts with oxygen and water to form sulfuric acid, which can fall to the ground as acid rain. Kilauea emits significant amounts of this gas (over two million tons per year), which reacts chemically in the atmosphere to form sulfate aerosol. Large explosive volcanic eruptions discharge so much sulfur aerosol into the stratosphere that they can reduce the Earth's ozone layer, alter the Earth's climate, and cause havoc across the globe. Downwind from the Kilauea vent, the erupting volcano's releases can produce acid rain and air pollution that pose persistent environmental and health problems. Large emissions of volcanic sulfur dioxide can react with oxygen, water and other elements to form a unique kind of toxic smog known as "vog." As scientists are increasingly learning, vog presents a health hazard and acid rain damages crops and water.[10]

Volcanoes also release enormous amounts of carbon dioxide into the atmosphere. This colorless, odorless gas usually does not pose an immediate hazard to life because it typically becomes quickly diluted to low concentrations, but concentrated levels can prove lethal to living things; it also accumulates in the atmosphere as a greenhouse gas that can contribute to global warming.[11] After earthquakes in the Sierra Nevadas at Mammoth Mountain, California, in 1989, scientists from the U.S. Geological Survey (USGS) recorded that carbon dioxide levels in some soil had risen to as high as 90 percent, compared to a normal level in the forest of about 1 percent. Gas from the young volcano was killing vegetation on the mountain, but a nearby local town had not been affected. This was a relief because if breathed at such high concentrations, carbon dioxide can asphyxiate animals and humans.[12] Today scientists are becoming more attuned to the dangers posed by carbon dioxide, particularly since it has recently become recognized as the most worrisome greenhouse gas.

Scientists have calculated that subaerial and submarine volcanoes together annually emit between about 130–230 million tons of carbon dioxide into the atmosphere. If this amount seems large, keep in mind that human activities release more than 150 times the amount of carbon dioxide emitted by volcanoes, or the equivalent of nearly 17,000 belching Kilaueas.[13]

As indicated by the Mammoth Mountain earthquake aftermath, carbon dioxide gas from inside the earth can invade low-lying areas and accumulate in the soil and water. High concentrations in these affected areas can harm people and animals, and decimate trees and other vegetation, turning much of the area around the volcano into a wasteland resembling the surface of the moon. Its effect on water is demonstrated by repeated natural disasters in Africa. Beautiful Lake Nyos sits atop a volcano in the highlands of western Cameroon. In 1986 the lake released a lethal cloud of silent, odorless and invisible carbon dioxide from a dissolving gas bubble that killed more than 1,700 people and hundreds of cattle, some of them up to 26 kilometers away. Two years earlier, a similar incident at another nearby lake also killed 37 people.[14]

Another naturally occurring substance, hydrogen fluoride (HF), is a fuming pale yellow liquid or gas with a strong odor. It attaches to fine ash particles that coat the vegetation and pollute the water. The federal Centers for Disease Control warns that exposure to even relatively low airborne concentrations can severely irritate eyes and skin, and produce bone degeneration and mottling of teeth. Fluorine often hurts or kills animals that eat the polluted grass; it also can harm marine life.[15]

Another toxic gas released by volcanoes, natural gas, hot springs, and crude petroleum is hydrogen sulfide (H_2S). It is commonly known as "sewer gas" for its offensive odor. This colorless, flammable gas is also produced by various industrial processes such as paper mills, coke ovens, and oil refineries. Humans can generally detect it at very low concentrations, but prolonged exposure to higher levels of the gas can cause the sense of smell to become fatigued, making this a particularly insidious poison. Federal health officials warn that 30-minute exposure to a high concentration of hydrogen sulfide results in irritated eyes, headache, dizziness, excitement, staggering gait, and diarrhea, sometimes leading to bronchitis or bronchopneumonia; in higher concentrations (greater than 500 parts per million) it can quickly cause respiratory paralysis and death.[16]

Volcanoes also emit large amounts of hydrogen chloride or hydrochloric acid, which can prove highly corrosive. When molten lava flows reach the ocean, the lava's extreme heat boils and vaporizes some of the roiling seawater, producing chemical reactions that become visible in an angry white plume called "lava haze" or "laze." This toxic mist is hazardous. Government warnings say exposure to low levels of such hydrochloric acid irritates mucous membranes of the eyes and respiratory tract, and exposure to higher concentrations can cause pulmonary edema and laryngeal spasm.[17]

Volcanoes have been terrorizing forms of life on Earth since the beginning, drastically altering the world's land forms, climate, and quality of life as much as any force of Nature. They have also shaped mythology and literature across the globe and prompted several major population migrations. An eruption of the volcanic island of Thera appears to have wiped out the Cretan civilization and spurred several Atlantis legends. Eruption of the Tambora volcano in Indonesia in 1815 directly killed as many as 100,000 people and resulted in a famine that also decimated several neighboring islands. Gases and dust particles released from the volcano drastically affected weather patterns around the world, contributing to other maladies such as cholera epidemics and food riots in Europe.[18] Another global catastrophe was set in motion on August 27, 1883 when the small volcanic island of Krakatoa off the coast of Java exploded into the stratosphere. The eruption unleashed a huge tsunami that killed 36,000 people and sent waves crashing as far away as France. The sound of the explosion was heard thousands of miles away. Krakatoa's volcanic dust swirled round the planet for years, lowering temperatures and causing sunsets around the globe to turn unusually red. The cataclysm also affected the world's political climate and precipitated a violent revolution by Muslim fundamentalists against Western colonial powers, after Muslim prelates on Java ascribed the calamity to Allah's punishment of the island's Dutch infidels.[19]

North America, and especially the United States, contains more supervolcanoes than any other part of the world. The largest single active volcano system lies beneath Yellowstone National Park. The last great eruption of the Yellowstone supervolcano, nicknamed "the beast," occurred 640,000 years ago. But at least two prior events happened at 600,000-year intervals, causing some scientists to predict that another one may be likely to occur soon. Such an eruption would produce the world's biggest explosion, spewing hot ash and choking sulfur dioxide across the globe and causing a volcanic winter. If that happens, it could be up to 2,500 times the size of the highly publicized 1980 Mount St. Helens eruption in Washington state, the deadliest and most destructive volcanic event in American history. Volcanic gases would transform the world again and possibly spell doom for millions, if not for the entire human race.[20]

Chapter 4

Nitrous Oxide: "This Wonder-Working Gas of Delight!"

In completing one discovery we never fail to get an imperfect knowledge of others of which we could have no idea before, so that we cannot solve one doubt without creating several new ones.

—Joseph Priestley, *Experiments and Observations on Different Kinds of Air* (1775–1786)

In late 1798 a new Superintendent was appointed for the Medical Pneumatic Institution in Bristol, England, an enterprise that had been established "for ascertaining how far the different gases, received into the lungs, were favourable, or not, to certain diseases," and how best to use them to treat patients.[1] The newcomer, Humphry Davy, was only 21 years old, but he already had displayed flashes of great brilliance. Despite being born to a humble woodcarver in Penzance, Cornwall, England, whose death had left him apprenticed to a surgeon-apothecary at age 16, Davy pursued his education with incredible zeal and landed the job at the institute after having studied chemistry for only four months and without ever having seen a single experiment conducted. Yet less than two years after his arrival, one observer was predicting that he might one day prove the likely successor to Isaac Newton.

Davy was as fearless as he was intelligent. A visitor who encountered him shortly after his arrival at the institute later recalled:

I soon learnt from Mr. D. himself the course of his experiments; many of which were in the highest degree hazardous, when, with friendly earnestness, I warned him against his imminent perils. He seemed to act, as if in case of sacrificing one life, he had two or three others in reserve on which he could fall back in case of necessity. . . . He has been known sometimes to breathe a deadly gas, with his finger on his pulse, to determine how much could be borne, before a serious declension occurred in the vital action.[2]

Davy intrepidly explored the wonders of all sorts of gases and combinations thereof, but one in particular captured his imagination. It was nitrous oxide. The Englishman Joseph Priestley had been the first to isolate and recognize something he called "dephlogisticated nitrous air," in 1772. Priestley had captured this delightful substance by heating iron filings he had dampened with nitric acid. After initially hoping that nitrous oxide might be suitable as a preserving agent, he moved on to studying other gases.[3]

Later, another scientist, the New Yorker Samuel Latham Mitchell (1764–1831), had warned that inhalation of nitrous oxide could result in rapid death. Knowledge of this history did not deter the inquisitive Davy, however, and he proceeded to carry out his own experiments with it. One day he exposed nitrous peroxide to iron, thereby removing three of the four oxygen atoms. Then he went ahead and inhaled it—and found that it produced a very pleasurable sensation. After satisfying himself that it was "respirable, and capable of supporting life for a longer time than any gas, except atmospheric air and oxygene," Davy replicated some of Priestley's experiments and conducted other tests of his own to explore its physiological effects. About one of them he wrote: "Having accidentally cut one of my fingers so as to lay bare a little muscle fibre, I introduced it while bleeding into a bottle of nitrous oxide; the blood that trickled from the wound became more purple; but the pain was neither alleviated nor increased." When he removed the hurt finger from the nitrous oxide, "the wound smarted more than it had done before." After it had stopped bleeding, he "inserted it through water into a vessel of nitrous gas; but it did not become more painful than before." The young scientist also tried the gas on a wide range of cold-blooded and warm-blooded animals and insects, and recorded how the gas had affected them.[4] Then in April 1799, he made his own first "inspiration" of pure nitrous oxide, noting that it "passed through the bronchia without stimulating the glottis, and produced no uneasy feelings in the lungs."[5]

Davy later performed another demonstration for his employer, the unusually short and fat Dr. Thomas Beddoes. Having previously closed his nostrils and exhausted his lungs, Davy breathed four quarters of nitrous oxide from his silk bag. His first feelings were similar to those produced in his previous experiment. But in less than half a minute, as he continued to breathe from the bag, those feelings were gradually "succeeded by a sensation analogous to gentle pressure on all muscles, attended by a highly pleasurable thrilling" in his chest and extremities. "The objects around me became dazzling and my hearing more acute," he wrote. Eventually, as the gas ran out, he regained his sense of muscular power, "and at last an irresistible propensity to action was indulged in." He adds, "I recollect but indefinitely what followed; I know my motions were varied and violent." He suffered no ill aftereffects.[6]

Davy's fascination with the gas would not dissipate. On the day after Christmas, he equipped himself with a curved thermometer inserted under his arm, and a stopwatch, then enclosed himself in an airtight breathing box with a capacity of about nine-and-a-half cubic feet as 20 quarts of nitrous oxide were put inside the box. Subsequent inhalations of the gas induced him to feel "a slight glow in his cheeks and a warmth spreading over his chest," after which he experienced "a sense of exhilaration similar to that produced by a small dose of wine, and a disposition to muscular exertion and merriment." Forty-five minutes later, he admitted another 20 quarts of the gas. "I now had a great disposition to laugh," he later wrote; "luminous points seemed frequently to pass before my eyes, my hearing was certainly more acute and I felt a pleasant lightness and power of exertion in my muscles."[7]

Immediately upon leaving the box, and not wanting to end his laughing enjoyment, Davy tried breathing some additional nitrous oxide. "I felt a sense of tangible extension highly pleasurable in every limb," he wrote:

> my visible impressions were dazzling and apparently magnified, I heard distinctly every sound in the room and was perfectly aware of my situation. By degrees as the pleasurable sensations increased, I lost all connection with external things; trains of vivid visible images rapidly passed through my mind and were connected with words in such a manner, as to produce perceptions perfectly novel. I existed in a world of newly connected and newly modified ideas. I theorized; I imagined that I made discoveries. When I was awakened from this semi-delirious trance by Dr. Kinglake, who took the bag from my mouth, indignation and pride were the first feelings produced by the sight of persons about me. My emotions were enthusiastic and sublime; and for a minute I walked round the room perfectly regardless of what was said to me. As I recovered my former state of mind, I felt an inclination to communicate the discoveries I had made during the experiment. I endeavoured to recall the ideas, they were feeble and indistinct; one collection of terms, however, presented itself; and with the most intense belief and prophetic manner, I exclaimed to Dr. Kinglake, "Nothing exists but thought! The Universe is composed of impressions, ideas, pleasures and pains!"[8]

On another occasion young Davy guzzled an entire bottle of wine, as a consequence of which he fell down drunk and went to sleep. He awoke with a sense of nausea, a splitting headache, and other usual hangover effects. But his binge was not over. Next Davy reached into his trusty green bag and breathed 12 quarts of nitrous oxide for three or four minutes, which consequently made him intoxicated again, though with no ill effects, and he paraded across the room, stamping, laughing, dancing, and vociferating, as if to demonstrate the gas's superiority.

The laughing part moved him to call the compound "laughing gas." Finding himself more strongly attracted than ever to nitrous oxide, Davy began to share his pleasurable discovery with others as a form of recreation, not only to display his own giddy behavior to spectators, but also to allow others to partake of the same delights. In one such encounter, involving three young gentlemen, the gas made one participant laugh, and another dance, but the third became pugnacious and punched Davy in the face.

Davy later called upon Dr. Beddoes to witness the effect his potent gas might produce on a female, and he prevailed on an intrepid young lady to breathe some of it from the little green bag. According to one account, after a few inspirations, to everyone's astonishment, the "young lady dashed out of the room and house, when, racing down Hope-square, she leaped over a great dog in her way, but being hotly pursued by the fleetest of her friends, the fair fugitive, or rather the temporary maniac, was at length overtaken and secured, without further damage."[9] Davy's laughing gas parties also drew a host of adventurous artists and writers including the poet Robert Southey and the potter Josiah Wedgewood. His friend, Samuel Coleridge, who was no stranger to the wonders of opium and other intoxicants, called inhaling nitrous oxide "the most unmingled pleasure" he had ever experienced. When asked why he attended so many public lectures on chemistry in London, the author of "Kubla Khan" replied: "To improve my stock of metaphors," and his fellow poet Southey offered as his own testimonial to the gas, "I am sure the air in heaven must be this wonder-working gas of delight."[10]

In 1800 Davy published a report, *Researches, Chemical and Philosophical; chiefly concerning nitrous oxide, or dephlogisticated nitrous air, and its respiration*, in which he recounted some of his activities. He had come to think the gas might hold enormous commercial potential, since it was superior to alcohol or opium in many respects and could replace them as the intoxicant of choice. He therefore invested considerable energy in devising a more efficient method to make it, and invented an apparatus that involved hydraulic bellows and a water tank. But his laughing gas craze did not catch on, on a mass scale.

As it would turn out, the greatest potential of the gas would lie not in its ability to create euphoria, but in one of its other effects, which Davy himself had noted. "As nitrous oxide in its extensive operation appears capable of destroying physical pain," he wrote, "it may probably be used with advantage during surgical operations in which no great effusion of blood takes place."[11]

Unfortunately, the medical profession did not pick up on this observation until well into the nineteenth century, leaving sufferers to rely on alcohol or opium to dull their agony. But this gradually began to change. In the 1820s a Scottish surgeon, Henry Hill Hickman, conducted gruesome experiments in which he immobilized animals with carbon dioxide and then amputated some of their limbs to see if they still felt the pain. They did—and his experiments went nowhere.[12] As a result, for 40 years after Davy's discoveries, nitrous oxide remained primarily used for private recreational purposes, particularly in public demonstrations wherein curious persons would pay a modest price to watch somebody act strangely.

It was not until the 1840s that medical practitioners attempted to introduce nitrous oxide as an anesthetic. It seems this came about by accident when a medical school dropout turned carnival huckster, Gardner Quincy Colton, toured New England staging nitrous oxide "capers." On December 10, 1844 the flamboyant Colton put on a grand exhibition at Union Hall in Hartford, Connecticut, equipped with what his flyer announced would be 40 gallons of laughing gas, promising that, "The effect of the Gas is to make those who inhale it either Laugh, Sing, Dance, Speak or Fight, and so forth, according to the leading trait of their character. They seem to retain consciousness enough not to say or do that which they would have occasion to regret."[13]

One of the onlookers that day was a local dentist, Dr. Horace Wells, who watched with amusement as one of Colton's volunteers, Samuel Cooley, inhaled some of the gas. Wells observed as Cooley charged wildly around the hall in a state of euphoria until the effects diminished. The observant dentist happened to notice that while Cooley was still enjoying the pleasurable effects of the gas, he had inadvertently bloodied his leg—but the reveler did not feel the pain until the gas had worn off. It immediately occurred to Wells that nitrous oxide might prove useful in dulling or blocking pain. So, after the demonstration, he invited Colton to join him in a demonstration. Colton agreed, and the following day, as instructed, a drugstore clerk administered a dose of the miraculous gas to Wells shortly before another local dentist extracted an impacted molar from Wells's mouth. "It is the greatest discovery ever made," Wells groggily proclaimed after the removal. "I didn't feel so much as the prick of a pin!"[14]

In January 1845, Dr. Wells arranged to demonstrate his wondrous discovery at the Harvard Medical School. This time the enterprising dentist treated a patient with nitrous oxide and proceeded to extract an infected tooth, but he had somehow mishandled the dose, and the patient howled with pain. Wells's audience booed him from the stage. From there it was downhill for Wells: he succumbed to drink and substance abuse, and died three years later. It was only after his death that medical textbooks began crediting him as the "Discoverer of Anesthesia."[15]

To this day, some dentists still consider nitrous oxide as a safe and popular painkiller, but it is not used for major surgery.[16] Its introduction in medicine also led to discoveries of other pain-relieving gases, which further revolutionized the field.

Ether has an even longer and equally colorful history. In about 1540 the German physician Valerius Cordus became the first person to synthesize the mysterious liquid, calling it "sweet oil of vitriol."[17] One of his contemporaries, the physician Paracelsus, noted that the oil put chickens to sleep.[18] In 1730 the German scientist August Frobenius renamed the potent liquid "ethereal spirits" or "ether." In the 1790s, researchers at Beddoes' Pneumatic Institution tried ether inhalation to treat patients with consumption (tuberculosis), but it was not successful. In 1818, Michael Faraday, one of Humphry Davy's protégés, noted that inhaling ether also produced some exhilarating effects, and "ether frolics" quickly became a popular diversion for medical students in Britain and the United States.[19]

The first successful effort to use ether as an anesthetic apparently took place in January 1842 in Rochester, New York when it was administered to a young female patient as a dentist extracted her tooth. Others did so about the same time. The American physician Crawford Long had participated in ether frolics while studying medicine at the University of Pennsylvania, and he too had envisioned using ether as an anesthetic. In March 1842, Long used ether to anesthetize James Venable, in order to remove a neck tumor. Long continued using ether anesthesia in his practice with some success, but his work remained largely unacknowledged because he did not publicize his results.[20]

Dr. Henry Bigelow, a surgeon at Boston's prestigious Massachusetts General Hospital, got wind of experiments by Wells's former dental partner, William Morton. On October 16, 1846 Bigelow invited the 27-year-old Morton to demonstrate the use of ether in the hospital's famous surgical amphitheatre. A crowd of skeptical physicians watched as Morton smoothly anesthetized a 20-year-old man so Bigelow could attempt to remove a vascular tumor from his neck. The operation went off without a scream and, turning to his stunned audience, Bigelow proclaimed, "Gentlemen—*this* is no humbug." Wild cheering erupted. Ether had been proved effective as a general anesthetic, and Morton's place in history was assured. Morton named his compound "letheon," and obtained a United States patent for it, but news of the discovery quickly spread to Europe before he could cash in on it.[21]

Shortly after Morton's triumph, one of his friends, Oliver Wendell Holmes Sr., suggested in a letter to Morton dated November 21, 1846 that he call the procedure *anæsthesia*. Many scholars credit Holmes as the person most responsible for its entry into the English language at that time. Within just a couple of years the terms "anesthesia" and "anesthetic" gained wide acceptance.[22]

Morton's feat electrified the medical world. Within weeks of his public demonstration, several respected surgeons conducted surgical operations using ether. A prominent London dentist, James Robinson, successfully performed a dental procedure on a Miss Lonsdale, using ether to block the pain. But ether proved to have a number of drawbacks: its high flammability made it hazardous to use, and the vapors tended to induce vomiting, which was also dangerous. Eventually researchers discovered that the correct dosage needed to be set with greater exactitude, depending in part on the room temperature. Somebody invented a device to control the amount to be inhaled precisely, but some of the other problems remained.[23]

Ether was soon supplanted by chloroform. Discovered in 1831 by the American physician Samuel Guthrie, the colorless, sweet-smelling liquid is highly volatile but nonflammable. By the late 1840s its anesthetic properties were also being studied. In 1847 a Scottish doctor, James Young Simpson, became the first to use chloroform successfully as an anesthetic. Although chloroform was considered more effective than nitrous oxide, researchers eventually learned that prolonged administration could cause many adverse health effects.[24] As many of its adherents found out, chloroform is susceptible to abuse. One of the best known examples of this was demonstrated by the sad case of Horace Wells. While trying to find a suitable alternative agent to nitrous oxide, Wells fell into a weeklong chloroform binge that resulted in his being arrested for assaulting a prostitute, and he ended up slitting his own throat in jail.[25]

But chloroform also achieved great respectability. In 1853, the famous British physician Dr. John Snow prescribed its use to Queen Victoria during the birth of her eighth child. After the successful delivery, other pregnant women quickly followed her example. Chloroform's use as a pain reliever in childbirth gradually became widely accepted, and by 1871 it had become Britain's favorite anesthetic. Its leading U.S. manufacturer, Edward R. Squibb of Brooklyn, estimated that of the country's 400,000 anesthetic administrations in 1870, chloroform was the agent used in half, ether in 40 percent, and other gases and mixtures for the remaining 10 percent. Over time its limitations became clearer: it turned out to be more toxic than ether. Consequently, the use of chloroform in childbirth gradually decreased.[26]

The developments in anesthesia that began with nitrous oxide demonstrated that gases can have many beneficial and even enjoyable uses. Within the space of just a few decades, scientists had pioneered the use of several different gases for medical purposes, to effectively block or reduce pain in individuals who otherwise would have suffered extreme discomfort—one of modern medicine's greatest achievements. So dramatic was this development that, by the end of the nineteenth century, man-made gases were often associated in the public mind with pain-relieving anesthesia and pleasurable sensations, not with agony and death.

Many of the researchers who had discovered the astonishing properties of man-made gases, and the practitioners and hucksters who had engineered their use in medical treatment, did not fare so well, however. Humphry Davy and many other intrepid chemists died premature deaths as a result of their exposure. (After experimenting with nitrous oxide, Davy had also inhaled numerous other gases.) In addition to Wells committing suicide, Morton spent the last seven years of his life in a mental asylum.[27]

Since Davy's time, a great deal more has also been learned about the workings of nitrous oxide. Besides being produced in Nature, from microbial action in tropical forests and other processes, it has also been manufactured in large quantities for many industrial purposes. Today, environmental scientists have found that nitrous oxide is also produced by chemical reactions in the atmosphere, where its peculiar qualities and reaction with ozone make it a major greenhouse gas and air pollutant. So, the gas is no longer simply a laughing matter.

Chapter 5

First World War

> No doubt in time chemistry will be used to lessen the suffering of the combatants.
>
> —Sir Lyon Playfair (1854)

Chlorine

Creating the Poisonous Cloud

Human beings were using chlorine long before they knew what it was or fully understood its properties. Archaeologists have found evidence that common salt or sodium chloride—the most common natural compound of chlorine—was used as early as 3000 BCE, and the first human-made compound of chlorine was probably hydrochloric acid (hydrogen chloride gas dissolved in water), prepared by the Arabian alchemist Rhazes around 900 CE. At about 1200 CE, medieval alchemists began using a substance called *aqua regia* (a mixture of nitric and hydrochloric acid) to dissolve gold, with one result being that it released irritating and nauseating gases containing chlorine. But alchemists had not yet studied these gases enough to know what they were. It was not until 1774 that chlorine was discovered. Its discoverer, Scheele, the Swedish apothecary, identified it as a chemical compound that he called "dephlogisticated marine acid air." In 1810–11 the English chemist Humphry Davy announced that chlorine was an element, which he named "chlorine" from the Greek *chloros* (green) because it was the same yellowish green color that sick plants sometimes develop.

Since that time probably the greatest advance in the history of chlorine occurred in the mid-nineteenth century when, during the terrifying London cholera epidemic of 1854, the British anesthetist and scientific detective John Snow discovered it could be effective in disinfecting the city's fatally contaminated water supply. Chlorine was also proven effective against typhoid and other water-borne diseases. It turned out to be a godsend.

Snow's breakthrough led governments to install municipal water filters and regulate their public water, thereby saving and extending countless lives throughout the world. But water chlorination came at a price. For in the early 1900s, scientists began to recognize more of its adverse effects, including its link to respiratory disease. Nevertheless, chlorine remained the dominant means of decontaminating water; it also proved useful in the production of bleach, antiseptics, medicines, petroleum products, solvents, paints, and other products.[1]

But chlorine had other, more lethal uses. Prior to the outbreak of the First World War in August 1914, the Prussian chemist Fritz Haber was already very knowledgeable about chlorine and its effects. After publishing his influential book, *The Thermodynamics of Technical Gas Reactions*, in 1905, he and Carl Bosch had invented a revolutionary new process to produce ammonia from nitrogen in the air. Ammonia held great importance, not only as fertilizer, but also in making explosives, and Haber's discovery elevated his status within Germany's powerful chemical industry. (The pair would later win the Nobel Prize for their discovery.) When the war started, Germany's dye industry already was working in high gear, producing over 5/6 of the world's dyes, and thus it enjoyed a great advantage in manufacturing high explosives, which many originally expected would ensure a quick military victory. Along the way, one of the things Haber had learned was that mixing ammonia with chlorine-containing compounds such as bleach would release highly toxic chlorine gas.

In 1911, Haber became director of the Kaiser Wilhelm Institute for Physical Chemistry in Berlin-Dahlem, Germany's premier chemical research unit. It was a position that soon would assume enormous military significance. When war was declared, Haber, a zealous patriotic nationalist, offered his services to the War Ministry and plunged into a number of key research projects involving motor fuels, high explosives, and other matters. For a time it appeared that Germany was ideally organized to fully exploit its chemical superiority, in part because the entire German dye industry was organized as one huge national trust. Under the parent corporation known as the *Interessen Gemeinschaft* (or IG) were a number of tightly controlled subsidiary companies and other entities closely linked with the armed forces.

The First World War introduced a slew of fearsome new weapons including submarines, airplanes, machine guns, tanks, long-range artillery and high-explosive shells. In August 1914, the first month of fighting, the French inaugurated another when they fired grenades containing a liquid irritant teargas (xylyl bromide) against the Germans. Two months later, the German army reciprocated by firing shells at French forces that contained a chemical irritant designed to induce violent fits of sneezing; then, on January 31, 1915, the Germans first used tear gas against the Russians on the Eastern Front. But it and a subsequent attempt against the French failed miserably.

Haber brought his expertise to the discussions about various gases. He knew that the chemical characteristics of chlorine in particular offered several advantages for chemical warfare. It is easily liquefied and boils at ordinary atmospheric pressure, so it would readily vaporize when the valve of a containing cylinder was opened. It is also 2½ times as heavy as air and can travel over a considerable distance before it dissipates into the atmosphere. And at ordinary atmospheric pressure and temperature, the greenish yellow gas has a very irritating effect on the membranes of the eyes, nose and throat that can incapacitate a person for weeks. Inhaling a heavy dose can prove fatal. Thus it could prove highly effective against an unprotected enemy. So, in December 1914 Haber suggested that the High Command consider using chlorine gas instead. He explained that it was well suited for current warfare conditions: when carried by the wind toward the enemy lines, the relatively heavy chlorine would sink into the trenches to produce violent coughing, blindness, and asphyxiation. By trying to escape its terrible effects, the enemy would thereby expose themselves to German gunfire. But unlike tear gas or sneeze gas, chlorine itself would also be lethal. Besides, the German chemical companies BASF, Hoechst, and Bayer already were producing large quantities of chlorine in their dye manufacturing, so they would welcome the contracts to make more. It was relatively easy to manufacture, and it could prove useful in turning out other likely war gases, since it was a key ingredient for making and supporting hydrochlorous acid, ethylene chlorhydrin (the basis for making mustard), phosgene, the lachrymator (tear-maker) chloroacetone, and many other toxic compounds. Thus, both in its own right and as a gateway into other poisons, chlorine seemed the place to start. Its main drawback as a war gas was that chlorine is a reactive substance, which meant that protection could probably be devised against it.

The Chief of the German General Staff liked the chlorine idea so much he had Haber promoted and put in charge of making the cylinders. But Haber's ideas were not popular with everyone. Some German commanders and chemists opposed the use of poison gas, following a long-held traditional view that resorting to poisons would violate the laws and customs of civilized warfare. Although the first recorded use of suffocating gases in warfare went back to at least 431 BCE, when the Spartans used sulfur fumes as a siege weapon, warriors ever since had largely disdained such tactics. Under the Hague Conventions of 1899 and 1907, by which Germany was still bound: "The Contracting Powers agree to abstain from all projectiles whose sole object is the diffusion of asphyxiating or deleterious gases."[2]

Therefore, as the Germans prepared to break the taboo against poison gas, their *spinmeisters* focused on drawing a distinction between *projectiles* filled with noxious gases that might be shot from artillery and *cylinders* that would be used to release such gases. The treaties, they claimed, might cover the former but not the latter, so that using a cylinder to deliver asphyxiating or deleterious gases did not appear to be outlawed. The Interessen Gemeinschaft started to put some of the gas into cylinders. "In no future war will the military be able to ignore poison gas," Haber said. "It is a higher form of killing."[3]

Toward evening on Thursday, April 22, 1915, Haber stood by at a vantage point opposite Langemark-Poelkapelle, north of Ypres in Flanders, as the Germans' 17-inch howitzers bombarded the French lines with screaming shells. Booms and whistles charged the air. Then the big moment arrived. Haber watched through his field glasses as the German troops proceeded to carry out his plan. Precisely on cue, the soldiers rushed to their stations along a four-mile front, taking only ten minutes to open all 5,730 pressurized cylinders, thereby releasing 168 tons of deadly yellowish-grey chlorine gas into the cool spring air. The westward wind carried the strange clouds racing fast and low over the pitted, muddy ground.

On the other side, the French and Algerian sentries saw something was afoot and, concerned that a smoke screen might be hiding an enemy advance, they ordered their men to "stand to," meaning the soldiers had to mount the trench fire step in preparation for a probable assault. The defenders' taut, exposed faces rimmed the sandbagged trench top. "Surprise and curiosity riveted us to the ground," one of them later recalled. "None of us knew what was going on. The smoke cloud grew thicker, which made us believe that the German trenches were on fire."[4] Then the cloud swept over them, and they smelled a foul scent like pepper and pineapple mixed together. Suddenly their eyes burned and they began to choke and stumble in the mist. Rifles fell from their grip. Some were drowning to death. Others who were meters behind them, hearing their cries and seeing the approaching cloud, fled in panic. But the gas overcame them. Horses whinnied and fell as birds dropped from the trees in the wake of the rolling cloud.

Minutes later, Anthony Hossack and other members of the Queen Victoria Rifles were resting in a meadow, six miles from the front. In the distance they could see an occasional flash from exploding shells in the dimming light. Some men, Hossack would later recall, began to follow the progress of a curious "low cloud of yellow-grey smoke or vapour, and, underlying everything, a dull confused murmuring." Racing to stay in front of it were a team of galloping horses, goaded by terrified riders, followed by more horses and men struggling to make their escape.[5]

Within an hour after the gas was unleashed, it had opened up a four-mile-wide gap in the Allied line. The Germans waited for the cloud to clear. Then two of their corps wearing primitive respirators finally advanced warily with fixed bayonets through the abandoned trenches and beyond, stepping over bodies and taking 2,000 agitated, coughing prisoners as they went.

In the meantime, the Germans' delay had enabled British and Canadian troops to counterattack and retake the position. One arriving British soldier, Private W. Hay of the Royal Scots, later described encountering civilians and soldiers suffering along the roadside. "We heard them say it was gas," he said. "We didn't know what the Hell gas was. . . . I was only twenty, so it was quite traumatic, and I've never forgotten, nor will [I] ever forget it."[6]

The Germans had altered the nature of warfare. From the first gas attack alone, the Allies lost 5,000 dead, and many more were seriously injured. But the greatest blow was psychological: the new weapon spread terror and panic.

Medical personnel did not know what malady they were dealing with or how to treat it. Gradually it became evident that chlorine gas destroyed its victims' bronchial tubes and lungs, resulting in their slow, hideous asphyxiation. A nurse described a typical victim's ordeal as follows: "He was sitting on the bed, fighting for breath, his lips plum coloured. He was a magnificent young Canadian, past all hope in the asphyxia of chlorine. I shall never forget the look in his eyes as he turned to me and gasped: 'I can't die! Is it possible that nothing can be done for me?' "[7]

Another gassing victim, Lance Sergeant Elmer Cotton, who lived to talk about his experience, explained the sensations as follows: "It produces a flooding of the lungs," he said;

> [I]t is an equivalent of death to drowning, only on dry land. The effects are these—a splitting headache and terrific thirst (to drink water is instant death), a knife-edge of pain in the lungs and the coughing up of a greenish froth off the stomach and the lungs, ending finally in insensibility and death. The colour of the skin turns a greenish black and yellow . . . and the eyes assume a glassy stare. It is a fiendish death to die.[8]

A Methodist minister who had witnessed the Ypres gas attack called it "the most fiendish, wicked thing I have ever seen."[9] Most everyone agreed. Much of the world recoiled in horror from the news. Haber's own wife was among them. After receiving her Ph.D. in chemistry, Clara Immerwahr had put aside her own work to support her husband's career. But in December 1914, one of Haber's co-workers—and the person who had introduced them—was killed in a laboratory accident that Clara subsequently learned was linked to her husband's secret poison-gas research. Then, after witnessing Haber's passionate advocacy of chlorine at the tear gas demonstration, she became even more upset, but to no avail, for her husband had scheduled a lavish party at their home to celebrate his Army promotion to captain. He had no intention of modifying his position. When Clara confronted him about his actions, the couple argued bitterly. Haber branded her a traitor to Germany, and she became despondent. Later that night of May 2, 1915, Clara took her husband's pistol and shot herself in the heart. Haber left for the front without completing the funeral arrangements. Years later, their son Ludwig described his father as "a brilliant mind and an extremely energetic organizer, determined, and also quite unscrupulous." Picking up the torch from his mother, he later condemned his father for having unleashed a monster on the world.[10]

Much to the Germans' relief, chlorine proved to be a potent psychological weapon. But the gas was visible, and Allied troops were soon able to spot and react to a gas release. Furthermore, chlorine's water solubility sometimes enabled a prospective victim to fend off some of its harmful effects by covering his mouth and nose with a damp cloth. Hence British and French troops were supplied with cotton pads and told that the ammonia in their urine would neutralize the chlorine. Some squeamish soldiers rejected that advice and kept their trousers buttoned. The Germans issued each soldier some cotton gauze pads and a bottle of sodium bicarbonate. As soon as the Allies learned of this they arranged for French nuns to begin making rudimentary pads with string ties, so that by April 24, 100,000 pads had arrived at the front. Over the next few years, both the Allies and the Central Powers devised a variety of other gas masks and filter respirators (using charcoal or antidote chemicals) to offer better protection. One of the earliest models, introduced by the British on July 6, 1915, consisted of a flannel bag with a transparent eye window, which entirely covered the head. Soon the gas masks became almost as important and variable as the gases themselves.[11]

The question of what projectiles were permissible under the Hague Convention quickly became moot, and its meaning was never put to the test. Soon the combatants would resort to dispersing poison gas in artillery shells and by other means as well. But countermeasures were one thing, and responding in kind was another.

Five months after Ypres, the British were finally ready to mount their own first chlorine gas attack. On the evening of September 24, 1915, 1,400 infantrymen commanded by Lieutenant-Colonel Charles Foulkes moved into position at Loos. They established 400 gas emplacements (although the Army insisted the word "gas" never be used and demanded the canisters only be referred to as "accessories.") The next morning at 5:20 A.M. Foulkes's men turned the cock on each cylinder, intermittently releasing a stream of smoke and chlorine gas for about 40 minutes. But something went horribly wrong; the wind changed its direction and speed and suddenly turned the poison back on the British themselves. As a result, they ended up suffering more casualties from their gas than the Germans. And the overwhelming sentiment of British soldiers toward gas, which had never been favorable to begin with, became even more disgruntled.[12]

Resorting to the use of chlorine had opened a Pandora's box. Armies on both sides of the conflict scrambled to devise better delivery systems; increase their poison-gas research, development, and manufacturing programs; improve their countermeasures and training; and generally adapt their strategies to meet the new realities of chemical warfare.

PHOSGENE

A Scent of Fresh-Cut Grass

Before their enemy could fully adjust to the dangers of chlorine, on December 9, 1915, the Germans moved to unveil another weapon against the British at Ypres. They waited until the wind was right. Then they sent a small band slinking out of their trenches to approach to within 100 yards or so of the enemy's line. On a signal, each of the Germans bent down and turned on a tap. A sentry heard the sound of gas streaming at great pressure from cylinders. But before he could fire, the gas was on him.

This time the cylinders contained the diabolical mixture called "White Star": a combination of chlorine and a deadly new war gas, "phosgene." The chlorine would have been bad enough, but on this occasion it was supplying the necessary vapor with which to carry the even more deadly phosgene, since the latter could not be used alone in gas cylinders due to its high boiling point of 8°C. The liquid phosgene quickly turned into a gas that spread very fast over the battleground, looking like smoke racing from a burning fuse; and indeed many soldiers mistook it for just that. As the fast-moving cloud filtered through, those in its path often detected the welcome scent of fresh-cut grass or green corn. By then it was too late. The British never knew what hit them. And before a man could telephone a warning, soldiers a mile or so behind him were already being hit as well.[13]

Phosgene did not prompt much coughing, which meant that more of it was inhaled. More often than not, its terrible effects were delayed. But it was a potent choking gas and lung irritant. A soldier who gulped a lethal dose might sense some irritation at first, and later even feel normal for several hours before the gas took hold. But phosgene was many times more lethal than chlorine.[14] The onset involved a burning sensation in the throat and eyes, along with coughing, followed by blurred vision, difficulty breathing, nausea and vomiting, and possibly lesions that resembled frostbite or burns on skin that had been exposed to the poison. In a few hours many victims developed fluid in the lungs (pulmonary edema), although sometimes the full effects did not begin until half a day had passed. Then the sufferer would have great difficulty breathing and begin to drown. As one nurse noted, "an abundant flow of thin watery fluid, often streaked with blood, simply flows from the mouth as the dying patient loses the power to expel it. After death, the foam from this fluid may dry to a white efflorescence around the mouth." Some victims were known to cough up four pints of yellowish liquid every hour before they finally expired. More often than not, even if the victim had not been fully exposed, he remained sick in hospital and was of no further use to the army.[15]

Although phosgene had not previously been used as a war gas, it had been around for years and was already manufactured by the Bayer Company and the Badische Anilin und Soda Fabrik for use in the production of dyestuffs including methyl violet. The French had also been exploring its potential as a war gas and had ordered some from their manufacturer, but it had not arrived yet.

Soon the French and British were also making phosgene. Germany discovered this at Verdun in February 1916 when the French responded with phosgene artillery shells. Four months later, the Germans started their final major attack by firing over 110,000 chemical shells filled with liquid phosgene. The French respirators could not filter out the agent, causing rows of masked artillery crews and snorting horses to collapse in their tracks. Medics trying to treat them were also stricken.

As a result, the Germans made an initial advance but could not sustain it due to a lack of troops. On July 9–10, 1916, they fired 63,000 chemical shells at the defenders, hoping for a repeat performance. But France had issued their artillerymen the more advanced M2 mask, which permitted enough to continue firing their guns well enough to halt the German advance. When it was over, the Germans had failed at Verdun.

In July 1916, the British also made their first use of phosgene at the First Battle of the Somme. They released 1,500 tons of phosgene mixed with chlorine along a 17-mile front. The racing cloud penetrated 12 miles behind the German lines, killing every unprotected living thing in its path: butterflies, birds, ants, beetles, mice, horses, and hundreds of Germans. In one instance, after the onslaught a Highlander who later surveyed the decimated German trenches came upon 250 corpses "lying huddled together," dead from the most lethal gas of the war.[16]

The British became particularly fond of using phosgene, after one of their officers invented a new kind of mortar that could hurl a 30-gallon drum of concentrated phosgene as far as 1,800 yards behind the German lines with deadly effect, thereby shattering the enemy's defensive positions. The weapon consisted of a crude-looking tube device about four feet long and eight inches in diameter that was buried in the ground and fired by means of an electrical charge delivered remotely from a safe distance. Batteries of 25 or so of the launchers were usually fired at once. Named after its inventor, Capt. F. H. Livens, the Livens Projector was inaugurated at the Battle of Arras on April 9, 1917.

According to one eyewitness account, after the batteries let loose their first discharge, "a dull red flash seemed to flicker all along the front as far as the eye could reach, and there was a slight ground tremor, followed a little later by a muffled roar, as 2,340 of these sinister projectiles hurtled through space, turning clumsily over and over, and some of them, no doubt, colliding with each other in flight." About twenty seconds later the cargo landed among masses of Germans; their steel cases were "burst open by the explosive charges inside, and nearly fifty tons of liquid phosgene were liberated which vaporized instantly and formed a cloud so dense that Livens, who watched the discharge from an airplane, noticed it still so thick as to be visible as it floated over Vimy and Bailleul villages."[17]

The British also developed a more mobile, special chemical Stokes mortar that could fire up to 20 rounds per minute.[18] The Germans invented the horrifying *Gaswerfer* 1918 that hurled canisters filled with phosgene-impregnated pumice granules over a distance of up to two miles.[19]

But ultimately the Germans were outgassed. The United States was fortunate that for some months before the war, the Oldbury Electrochemical Company had been working on the utilization of their waste carbon monoxide in making phosgene. The company shared these results with the government, and the process was utilized at the Edgewood plant to make phosgene for battlefield use. Its manufacture required chlorine and carbon monoxide, both of which were produced in massive quantities. Soon the United States was turning out phosgene in huge volume for use against Germany.[20]

Mustard

Drowning Under a Green Sea

At 10 P.M. on July 12, 1917, British troops along the front line at Ypres came under heavy bombardment from German artillery that lasted into the next day. The exploding shells exuded an obnoxious gas that caused some gunners to sneeze and tear up. The soldiers also noticed a horrid smell like rancid garlic or mustard stinking up the warm summer night. A few began to detect a sticky, oily substance splattered on the ground, which some of them made the mistake of stepping on. The liquid's brown or green color was easy to overlook in the muddy darkness. At first the effects seemed so relatively innocuous—only a slight irritation of the eyes and throat—that some in the trenches loosened or removed their gas masks in order to breathe and sleep more easily.

Several hours later, however, men began writhing and calling out in terrible pain. Their eyes were afire, and patches of boots, uniform or skin that had come in contact with vapors from the mystery substance were now covered with excruciating blisters and sores. The fumes left them blinded and clutching their throats in the darkness, gasping for breath and drowning as from some hideous plague. Even someone who had kept his mask on began to display symptoms; the insidious stuff had worked its way through his clothes and invaded his eyes and buttocks, scrotum and penis.

Within a day or two of the July 12 attack, dozens were dead or dying, and hundreds more required long-term hospitalization. Samples from the German shell casings bearing a yellow cross and other markings were sent back to the lab for analysis; the word came back that it was something new. Some English soldiers called it "Yellow Cross" based on its distinctive markings. The French referred to it as Yperite. But most people would know it as mustard.[21]

Long before the Germans introduced mustard on the battlefield, numerous scientists had stumbled across one or another version of the compound. Fifty years earlier, the German chemist Albert Niemann (who today is best remembered for having isolated cocaine from the coca plant leaf) noted that "the minutest trace which may accidentally come in contact with any portion of the skin, though at first it causes no pain, produces in the course of a few hours, a reddening and on the following day, a severe blister which suppurates for a long time and is very difficult to heal."[22]

In 1886 the German Viktor Meyer reacted ethyl chlorohydrin with sodium sulfide to produce an oily but otherwise unremarkable compound, thiodiglycol.

What happened next was unexpected. For when his assistant ran a reaction that attached two chloride atoms, the final product caused the apprentice to suffer serious injury to his eyes and he became progressively sicker. Meyer sent a sample of the curious product to a medical college. Rabbits exposed to its vapors quickly contracted conjunctivitis and abrasions on their skin that resembled the injuries suffered by Meyer's helper. Then the rabbits died. Meyer later published a scientific paper noting his experiments.[23]

By the time the war broke out, numerous German scientists, including Fritz Haber, were aware of mustard's high toxicity and capacity for use as a chemical weapon; however, they suspected that the Allies also knew of its potential, so they proceeded cautiously. Although mustard had not been produced in quantity before the war, Germany's dye industry already possessed all of the intermediaries necessary for its manufacture, and they also had the skilled and trained workforce required to make it.[24] Two German chemists, W. Lommel at Bayer and Wilhelm Steinkopf, working at the Kaiser Wilhelm Institute, created a potent new substance that was named "Lost."[25] But Haber had the Army hold off on introducing it until they had a large enough stock of the precursor on hand to ensure they would be able to manufacture a large volume. That way they would have a jump of at least several months over the enemy. In that period, he hoped, Germany's large-scale exclusive use of the new weapon might help them win the war.[26]

Until that point, the early idea behind gas warfare had been that a war gas should have a relatively high vapor pressure in order to provide a concentration sufficiently high to cause casualties through inhalation. But mustard turned out to be the king of war gases, even though it had a very low vapor pressure, because it offered several advantages over other poisons. A few shells with mustard fired in an area were enough to generate casualties for hours and days afterward. Durable and persistent, it did not dissipate like other gases. Even if it froze during the winter, it could remain toxic upon thawing in the spring. Persons who came in contact with the oily fluid were vulnerable to painful injury or death. For a time it appeared that Germany might have hit upon a winning formula: its dye industry could continue to manufacture ample quantities, whereas the Allies were not as well equipped to produce bulk amounts of chlorohydrin.[27] Or so it seemed.

Following through with Haber's plan, during one ten-day period in the fall of 1917, the Germans fired over one million shells containing 2,500 tons of mustard gas at the British on the Ypres salient. As a result, the British suffered almost as many gas casualties as they had from all the other gas attacks during the previous year of the war. However, the weapon significantly delayed but ultimately did not prevent the British advance. Although mustard killed only 2 percent of its victims, compared to 8 percent from rifle fire, it did inflict substantial suffering and had a profound psychological effect. The Germans also developed strategies to employ mustard gas before one of their own attacks, as a means of wearing down the enemy's strength and morale.

The Allies were under tremendous pressure to come up with vast quantities of mustard in order to beat the Germans at their own game.[28] In fact, the French were not able to begin using mustard until June 1918. The British took over a year to develop their own mustard gas, and they were not able to begin using it until September 1918. What saved the day for the Allies was that by the end of the war the United States had developed a new process to produce 30 tons of mustard per day—more than England, France, and Germany combined—using sulfur monochloride. Had the war continued through 1919, that U.S. capacity would have been more than quintupled by its line of newly funded factories. The U.S. brand of mustard contained 17–18 percent sulfur in solution, which proved even more effective than the German kind in producing casualties. Thus, Germany was doomed to suffer more damage from mustard than it inflicted.[29]

Mustard caused immense suffering. Conservative estimates place the number of persons exposed to mustard gas in World War I at 400,000, with a 3 percent fatality rate. Unless a large lethal dose of the gas was inhaled, the effects proved to be relatively slow, but after this latent period, the injuries became more severe. Some of the effects were called "chemical pneumonia"—high fever, stertorous breathing, and stupor; the lungs filled with frothy fluid, and the victim gasped, wheezed and choked. Lines of blinded soldiers with bandaged eyes being led away from the front became a common sight. As one nurse on the Western Front described the early effects of mustard: "[T]he poor things [are] all burnt and blistered all over with great suppurating blisters, with blind eyes—sometimes temporally, some times permanently—all sticky and stuck together, and always fighting for breath, their voices a whisper, saying their throats are closing and they know they are going to choke."[30]

The U.S. commanders struggled to train their inexperienced soldiers in ways to survive chemical attacks. Upon arriving in France, every doughboy had to undergo special gas training that included constant gas mask drills and immersion in a chamber full of actual war gas. In order to get the green recruits to pay attention, somebody came up with the idea of utilizing sports celebrities as their gas trainers. Among those they selected for the task were several of the top professional baseball players of the day, including Ty Cobb and Christy Mathewson. In October 1918 the immortal ballplayer Cobb was commissioned as a captain and assigned to help train hundreds of doughboys at the Allied Expeditionary Force's (AEF) headquarters in Chaumont. He recalled what it was like to put trainees through the gas chamber when it was flooded with mustard or other deadly gases. "The stuff we turned loose was the [real] McCoy," he wrote, "and meant to train a man to be on the *qui vive*—or else."[31] At the trainer's hand signal, each man was required to instantly snap his mask into position. But one day, some of the men missed their signals, and ended up inhaling some gas, which caused a panic. "As soon as I realized what had happened," said Cobb, "but only after inhaling some gas, I fixed my mask, groped my way to the wall, and worked through the thrashing bodies to the door. Trying to lead the men out was hopeless. It was each one of us in there for himself." He felt the aftereffects for weeks, but he was one of the luckier ones. For as he later told it, the gas had felled sixteen soldiers and eight of them died within hours. One of those severely injured was his fellow ballplayer, Mathewson (baseball's all-time greatest pitcher). Cobb said Mathewson later told him, "Ty, I got a good dose of the stuff. I feel terrible." Mathewson was subsequently diagnosed with "tuberculosis" in both lungs, and he died seven years later at the age of 45. Cobb always blamed the gas, though he never knew what kind it was.[32]

Douglas MacArthur was one of the luckier (albeit foolish) ones. As a colonel in France with the AEF, MacArthur was gassed twice—once in March 1918, after he had removed a blindfold and the poison vapor threatened his sight, and another time on the night of October 11, 1918, when he failed to wear a mask and was exposed to tear gas and mustard, after which he became extremely sick but refused hospitalization.[33] (My great uncle Philo Dutton was also gassed during the war, but he survived and later gave me his helmet and gas mask.)

Some of the worst gas-related casualties occurred among the workers of the mustard gas plants. At England's Avonmouth factory, a medical report issued a few weeks after the Armistice revealed that among its 1,100 workers there were seven deaths, more than 1,000 burns and over 1,400 illnesses.[34] The U.S. Army's official figures indicated that in the period June to December 1918 alone Edgewood Arsenal suffered 925 casualties—769 of them from August through October. Mustard gas accounted for the lion's share—674 of the total.[35]

After World War I, mustard gas was used again in several conflicts, but it never again achieved the status it had occupied in 1917–18.*

LEWISITE

The Plan to Exterminate Berlin

In 1917, Captain Winford Lee Lewis of the U.S. Army was working on war gas research at Catholic University in Washington when he came across information about some earlier laboratory experiments that had been performed there. It seemed that in 1903 Father Julius Aloysius Nieuwland, a graduate student in chemistry there, had been exploring the properties of acetylene. Nieuwland

*In 1919 the United Kingdom used it against the Red Army. Spain dropped it from airplanes against insurgents in Morocco in 1921–27. Fascist Italy used it against Libyan rebels in 1930 and against Ethiopian forces and civilians in Abyssinia in 1935–40. The Soviet Union sprayed mustard from warplanes against the Basmachi in Central Asia in 1934 and 1936–37. During the German invasion of Poland in 1939, Polish fighters used mustard agent to injure 14 German invaders near Jaslo, and the Germans dropped sulfur-mustard bombs on a Warsaw suburb, supposedly by mistake. Imperial Japan repeatedly used mustard gas on the Chinese in 1937–45. Egypt employed mustard in North Yemen in 1963–67. Iraq gassed the Kurds with it in 1965. The Vietnamese may have used it in Laos and Cambodia in 1976–80. Iraq used it against Iran in 1981 and on Iraqi Kurds in 1988. Iran may have reciprocated by mustard-gassing Iraqis in 1987-1988. Armenians may have used it against the Azerbaijanis in 1992. And Sudan may have used it against insurgents in 1995 and 1997. Harris & Paxman.

had just combined some acetylene with arsenic trichloride and added aluminum chloride as a catalyst. The mixture bubbled and gave off a wisp of black smoke that smelled like geraniums. But the arsenic compound was highly toxic; Nieuwland caught a whiff of it that caused him to spend several days in the hospital. Lewis sought to investigate whether the compound might hold any value as a weapon, so he cautiously retraced Nieuwland's steps and purified the substance into an oily, amber liquid that burst into flame when exposed to water. Luckily, he was not injured. Tests revealed the gas to be extraordinarily lethal, prompting Lewis to immediately turn it over to the Chemical Warfare Service.[36]

The Army assigned the compound to undergo further research at American University's Experimental Station (AUES), under a team led by a scientific prodigy named James Bryant Conant. Conant explored ways to contain its high volatility so it might offer some usefulness as a chemical weapon. He and his team tested specimens of it on snails, slugs, mice, rats, guinea pigs, canaries, dogs, monkeys, and goats, meticulously recording the effects and then subjecting the carcasses to postmortem examination.[37] The chemists also utilized a squat barracks, known as the "Man Test Laboratory," that was equipped with a large bathtub full of soapsuds and cages holding canaries that were supposed to provide advance notice if the air became too poisonous.[38] One American soldier who was exposed to lewisite there and lived to tell the tale, Sgt. George Temple, later said he believed that a higher percentage of his countrymen were killed by gas at the AUES than died in battle.[39] The director of the research division, Col. George A. Burrell, affirmed that the AUES casualty rate exceeded that of any other unit except the deadly mustard gas-manufacturing unit at Edgewood Arsenal.[40]

Lewisite could kill by absorption through the skin or inhalation. Within ten to twelve seconds, a few drops of liquid lewisite on the skin produced an immediate stinging and burning sensation at the affected site. Within the next five to fifteen minutes the skin took on a cooked appearance, characteristically dull dead-white or grayish in color, as might appear after an acid burn. Shortly thereafter, erythema or redness developed around the contaminated spot. Lemon-colored welts appeared. Then the skin puckered around adnexal orifices to give the appearance of "tanned pigskin." Six to eight hours later, tiny blisters appeared, shortly replaced by large bullae that covered the entire rash area. Characteristically there was a very sharp line of demarcation between lewisite-burned skin and normal skin, making it fairly simple to distinguish between the burn of lewisite and sulfur mustard. Delivery of a large quantity of lewisite to intact skin over a prolonged period could result in deep penetration through subcutaneous tissue into muscle, with attendant edema (buildup of fluid in the tissues) and necrosis (the pathologic death of living tissue). The onslaught of symptoms came to be known as "lewisite shock."[41]

Within a few months, Conant's team judged the substance, code-named "methyl" or "lewisite," to be the most poisonous substance yet discovered—some claimed it was 72 times more lethal than mustard gas—and the Army was eager to put it to work. Conant was ordered to make as much of it as he could as fast as he could, for it had been classified as the nation's most important secret weapon.

In early 1918 Conant set up shop in an abandoned auto plant in Willoughby, Ohio, near Cleveland. He instituted tight security and brought in hundreds of soldiers who worked around the clock. It was there, he hoped, that the material now known only by its top-secret designation of G-34 would become "the great American gas which would win the war."[42]

In July 1918, General William L. Sibert, the head of America's chemical warfare program, ordered that 3,000 tons of the methyl in shell and drums must be ready on March 1, 1919. The Army's secret plan for the spring 1919 offensive called for a massive use of poison gas that would have turned the fighting into largely a chemical war. The strategy included a series of aerial attacks that would unload tons of mustard on German strongholds and dump deadly payloads of lewisite (which General Amos Fries called "The Dew of Death") and other gases on Berlin with the aim of annihilating its entire population.[43]

At its peak, Conant's workforce geared up their machinery to produce an awesome output of ten tons a day—one ton more than what could have "depopulated" Manhattan, a city of four million people. This volume was more than 10 times greater than the Germans' total output of poison gas, but Conant's variety was seven times more deadly than theirs—theoretically more than enough to exterminate Berlin. Remarkably, although many workers at the Willoughby received serious burns as a result of their work, none of them died, and there was no catastrophic accident.[44]

By late fall 1918, the methyl was packed into 155-millimeter shells and drums that were intended for bombardment from aeroplanes. As Colonel Walker at Edgewood Arsenal later explained:

> Our idea was to have containers that would hold a ton of mustard gas carried over fortresses like Metz and Coblenz by plane, and released with a time fuse arranged for explosion several hundred feet above the forts. The mustard gas, being heavier than air, would then slowly settle while it also dispersed. A one-ton container could thus be made to account for perhaps an acre or more of territory, and not one living thing, not even a rat, would live through it. The planes were made and successfully demonstrated, the containers were made, and we were turning out the mustard gas in the requisite quantities in September.[45]

Few histories of the war have mentioned the plan to bomb German cities with poison chemicals. One historian has contended that the Allies would not have used gas bombing "unless they had to," and noted that the published record of the Supreme War Council does not include mention of such a possible use of gas in the spring of 1919.[46] It is unclear whether the German high command believed that the Allies could actually carry out such threats involving gas. But it is conceivable that the Kaiser's abrupt decision to surrender, effective

November 11, may have been influenced by fears about the annihilation of Berlin and other cities.[47] We may never know if the Germans were warned what would happen if they did not capitulate. But it is striking that twentieth-century historians have not questioned what, if any, debate went on within U.S. military and civilian ranks over the possible use of such weapons of mass destruction against civilian targets. It is also striking that historians have not closely examined the parallels between the decision to use gas against German cities in World War I and the plan to use the atomic bomb on Japanese cities in World War II.

Estimates of the First World War's final toll of casualties were both vast and hugely divergent. By all accounts the war killed an estimated 8.5 million persons and wounded 21 million others, including 1.3 million losses from the new horrors of chemical warfare. Civilians accounted for as many as 9–13 million casualties, marking an end to "civilized" warfare.[48] Although about 27.3 percent of U.S. battlefield casualties (74,779 of 274,217) were officially attributed to gas, the real numbers were much higher, as the government did not acknowledge the thousands of delayed but premature deaths, such as Christy Mathewson's, that actually had been caused by chemical weapons. Had the conflict continued, the war's toll from gas certainly would have skyrocketed, especially for civilians. As it was, a following epidemic of influenza that many linked to conditions produced by the war claimed a mind-boggling 50–100 million lives across the globe—675,000 of them in the United States.[49]

The Armistice left tons of deadly lewisite in anxious American hands. Nobody knew how to dispose of it. Cleveland did not want the deadly stuff dumped into Lake Erie, and there was no practical way to neutralize it. Scientists estimated there was almost enough of the poison left to kill every man, woman and child in the United States. Dumping it into the ocean seemed the only option.

Because no one knew what to do with it, the U.S. government shipped its supply of lewisite to Baltimore via hair-raising rail transport and loaded the 364 55-gallon drums of the lethal cargo onto ships. The ships then took it 50 miles out into the Atlantic; workers dumped it into the sea at three-miles depth in undisclosed and unmarked locations—oblivious to the dangers posed by its inevitable leakage.[50] (See Chapter 15.)

Shortly after the war, newspaper and magazine stories that described America's secret weapon began to appear. In 1919 the *Cleveland Plain Dealer* reported that methyl was 72 times more lethal than mustard gas and would have killed half the German army. *Harper's* magazine, *The New York Times*, and other publications called it the most deadly weapon of mass destruction yet invented, but General Fries dismissed some of the accounts as "wild stories."[51] By the early 1920s the secret formula for lewisite had been reprinted in international scientific journals, and several nations mounted clandestine programs to develop it as part of their own chemical warfare arsenal.

None of America's inventors and promoters of poison gas expressed regret about what they had done. As his role as a gas researcher became known, Father Nieuwland defended chemical weapons as intended "not to kill but to incapacitate." (In 1936 he suffered a fatal heart attack while visiting the Catholic University laboratory where he had first synthesized the compound.) Winford Lewis often spoke publicly about his involvement in developing the poison gas and steadfastly defended its use, saying that powers capable of developing more advanced chemical weapons were higher on the evolutionary scale and more deserving of victory. (After becoming partially paralyzed, he slipped on his porch and died in 1943, at age 64.) James Conant would go on to become the most famous of all the lewisite figures. In 1940, as war again consumed Europe, he was tapped to direct a division of the National Defense Research Committee, which supervised production of bombs, fuels, gases, and chemical agents. Conant helped the United States produce 20,000 tons of lewisite and tons of other chemical agents for World War II, and tested the poisons on thousands of American GIs. (In his most important role, Conant ran the government end of the Manhattan Project that built the atomic bomb.)[52]

Decades later, in the 1990s, landscapers on the American University campus unearthed some old debris dating back to Conant's AUES days. Fumes from the broken bottles sickened the workers, and they had to be hospitalized. Health officials determined they had been poisoned with lewisite. On September 3, 2003, the Army Corps of Engineers revealed they had unearthed a vial containing "about a teaspoon" of lewisite—more than enough to kill someone. As of 2004 the government was still trying to clean up the Spring Valley neighborhood in Washington, D.C., having already spent $91 million to do so. Over a hundred residences and businesses showed arsenic levels higher than 20 parts per million, which required remediation. Even after the government spent millions cleaning up the site, soil samples taken in 2004 revealed there were still high concentrations of arsenic at 140 homes and businesses.[53]

Chapter 6

Hydrogen Cyanide: The Gas Chamber Is Born

After the First World War, people across the globe strongly condemned gas warfare. In 1919 the Versailles Treaty forbade the "use of asphyxiating, poisonous or other gases and all analogous liquids, materials, or devices being prohibited, their manufacture and importation"—albeit only in Germany—and President Woodrow Wilson called for a worldwide ban on chemical weapons.[1] But the U.S. Congress dragged its feet. Republican Warren Harding, who swept into the White House in 1921, also favored curtailing chemical warfare. World opinion, including American public opinion, overwhelmingly abhorred poison gas weapons. The revulsion reached its apex in 1925, when 38 powers, including the United States signed the Geneva Protocol banning chemical warfare. Yet the process required ratification by the individual governments, and before that could occur, the U.S. Chemical Warfare Service (CWS) and the chemical industry waged a massive public relations campaign to stop it.[2] Somehow, the poison lobby succeeded, and military leaders did all they could to keep abreast of any new developments that could affect the state of chemical warfare.

The chief of the CWS, Gen. Amos Fries, called lethal gas "the most powerful and the most humane method of warfare ever invented," and insisted the United States must retain the strategic advantage it had won during the war.[3] Fries built part of his winning lobbying effort on partnerships to provide "constructive" peacetime uses for the research, technology and material that supported chemical warfare, claiming it would benefit American society as a whole. He said knowledge of poison gas's qualities could help fight disease, increase farm yield, advance mining interests, and rid society of rats, insects and other pests. At his urging, the Department of the Interior promoted the use of gas masks in refrigeration plants, firefighting, and other settings; agriculture officials employed phosgene to kill rats and gophers; and the use of chlorine as a disinfectant was expanded. Industry spokesmen claimed chlorine gas would eliminate influenza, mustard gas would cure tuberculosis, and lewisite might be an effective remedy for syphilis-related maladies.[4]

Federal officials ignored or suppressed evidence about the environmental damage caused by chemical warfare, although the government's own gas experiments had shown a "resultant damage to vegetation" and other harmful effects.[5]

Fries and his allies steadfastly denied that exposure to poison gases at the front had caused any ill health effects for American soldiers, even though thousands of veterans (like Christy Mathewson) were suffering from severe respiratory diseases and other problems.[6] On the contrary, Fries claimed that inhaling chlorine gas would cure the common cold and ward off disease. President Calvin Coolidge had himself subjected to such treatments, and later said he was cured.[7] Fries called war gases a boon to the human race.[8]

After the war, research on the killing power of lethal gases was supposedly fixed on insect and small animal extermination. Fries acknowledged having given pest removal "a good deal of attention," and added he expected "to give a great deal more to it in the future." He also quipped, "The . . . years that have elapsed since the close of the war have shown us that the human pest is the worst of all pests to handle."[9] Pest control and warfare shared much in common.[10] Research in one area often proved useful for the other and gave the government a stake in fostering pesticide research and manufacture in peacetime. Pesticides' long-range effects on the environment and human health were not considered.

In the early 1920s some of the most far-reaching "constructive" government chemical activities involved cyanide. The substance is found in sugar beets, cassava roots, large fruit pits and tobacco leaves. Hydrogen cyanide was discovered in 1782; it is a colorless or pale blue liquid or gas having an odor like bitter almonds, although some persons cannot detect the scent. It is also known as hydrocyanic acid gas (HCN), Prussic acid, or "Berlin blue acid" due to its intensely blue pigment. If taken by mouth in salt form, such as potassium cyanide, stomach acid converts the cyanide to volatile hydrogen cyanide, with fatal results. Both the liquid and vapor are acutely poisonous if absorbed through the lungs, skin or eyes. Massive doses are likely to cause sudden loss of unconsciousness, asphyxiation, and death from respiratory arrest. Exposure to cyanide gas can cause salivation, nausea, vomiting, hypernea (increased depth of breathing), dyspnea (difficulty breathing), an irregular or weak pulse, anxiety, confusion, tachypnea (rapid breathing), vertigo, giddiness, stiffness of the jaw, and neurasthenia (fatigue).[11]

While cyanide had not been used very extensively as a war gas in the First World War, research had shown it to have many possible uses in twentieth-century industrial society. Promoters first employed hydrocyanic acid gas as a fumigant for insect-control purposes in 1886 and first used it to control insects in greenhouses in 1894; in 1898 they began using it in some homes for insect control; in 1905 they advocated its application for control of the cigarette beetle; in 1912 they utilized it for ship fumigation and got it adopted by the U.S. Department of Health as a standard fumigant; liquid hydrogen cyanide was first tested for insect control purposes in 1915; in 1917 HCN fumigation methods were developed for control of insects affecting the florist industry, and liquid HCN was introduced commercially.[12] Consequently, by the mid-1920s, modern industrial society prized cyanide. Despite its poisonous characteristics, it was also being widely in photographic processing, steel hardening, electroplating, pharmaceutical production, and especially in mining, where it served to separate ores.[13]

Before World War I, the sale of cyanide in the United States was exclusively controlled by German firms.[14] The only cyanide manufacturer in the United States was Roessler & Hasslacher, which had begun to manufacture it in New Jersey in 1894.[15] Although the company was nominally based in the United States and headed by Franz Roessler, it was actually a long-established German-controlled enterprise that had been founded by his brother Hector Roessler, as part of the large German chemical concern DEGUSSA (*Deutsche Gold und Silber Scheideanstalt*) of Frankfurt-am-Main, which sold all of the cyanide for the German producers.[16] Sale of cyanide was tightly controlled by an international cartel, which aimed to restrict the supply and thereby control the price; under this system, the Germans continued to dominate the U.S. market while cloaking their ownership and control so as to avoid seizure by the American Alien Property Custodian. After the war, DEGUSSA was ostensibly stripped of Roessler & Hasslacher, along with its Hoboken plant and other shareholdings and patent rights.[17] Shares in the company were sold at public auction under the Alien Enemy Act.[18] Behind the scenes, though, the Germans and the cartel still retained control.

American industry continued to find more uses for cyanide. With the blessing of U.S. Surgeon General Hugh Cumming, federal employees carried out large-scale citrus crop fumigation using hydrocyanic acid gas. Although the United States Department of Agriculture reported on the quantity of the poison that was absorbed by various foodstuffs, the agency did not dare offer any conclusions about whether fumigated foods were safe for consumption, saying only that such conclusions "lie in the domain of the pharmacologist."[19] Indeed, no federal agency would challenge the pervasive use of poisons in the nation's food, water supply, and air.

Scientists had established that typhus, one of the worst killers in human history, was spread by lice from rats, and cyanide was found to be effective at killing the pests. Therefore the U.S. government employed HCN to fumigate ships in port, even though the practice resulted in numerous deaths. Incredible as it may seem today, the U.S. Public Health Service also encouraged the use of a new, most potent form of hydrocyanic acid, Zyklon, to "delouse" the clothes and living quarters of prisoners and immigrants. Federal border agents in Texas sprayed the deadly poison on the clothes and bodies of tens of thousands of incoming Mexicans arriving from Juárez.[20]

Chemical executives in Germany closely followed these developments and enjoyed the fat profits. Dr. Gerhard Peters of DEGESCH, a chemist who had worked under Haber at the Kaiser Wilhelm Institute, authored numerous articles in scientific and trade journals about the virtues of Zyklon for preventing disease, especially typhus, and he approvingly cited the Americans' use of the poison on Mexican immigrants.[21] (After World War II, Peters was brought up on war crimes charges and sentenced to five years in prison for complicity in the extermination of Jews using Zyklon-B.) DEGUSSA had made a remarkable recovery in the 1920s, spurred by the cyanide operations of its German subsidiary DEGESCH, which was a successor to the War Ministry's Technical Committee for Pest Control headed by Fritz Haber.[22]

During the First World War, hundreds of thousands of American military personnel had undergone immersion in enclosed spaces full of lethal agents, for research or training purposes. This had been done under controlled conditions in which the subjects usually wore gas masks and took other precautions, and it had made the gas chamber a common fixture of modern war preparedness. But the gas chamber had other potential uses as well. Starting in the 1920s, lethal gas was touted as the quickest, most painless, and most humane means of executing criminals—a "gentle" way of killing.

Since the 1870s, some animal shelters in London, New York and other cities had started using carbonic acid gas to asphyxiate dogs and cats. In 1884, Sir Benjamin Ward Richardson, a British pioneer in anesthesiology, delivered a lecture to the Society of Arts in London entitled "On the Painless Extinction of Life in the Lower Animals," based on his design of a special wood-and-glass chamber into which gas was pumped to carry out animal euthanasia.[23]

Many proponents of the growing movement of eugenics (which sought to improve the human race through selective breeding and other means) also embraced the notion of a "lethal chamber" that would rid society of unwanted burdens, such as insane and chronically ill or deformed persons, habitual criminals, degenerates, and other members of the unfit and defective classes. The British novelist D. H. Lawrence wrote of giving "three cheers for the inventors of poison gas," and said: "If I had my way, I would build a lethal chamber as big as the Crystal Palace, with a military band playing softly, and a Cinematograph working brightly, and then I'd go out in back streets and main streets and bring them all in, all the sick . . . the maimed; I would lead them gently, and they would smile me a weary thanks."[24] Popular talk about use of a lethal chamber for euthanasia became part of Victorian discourse, while the moral and practical aspects surrounding its introduction were largely swept under the rug or glossed over.[25] It appears to have been in the late 1880s that the institution of a lethal chamber to execute criminals was first seriously considered.

A breakthrough occurred when a blue-ribbon commission in New York State was charged with finding a more humane manner of execution to replace hanging. The four methods considered were electrocution, the guillotine, the garrote, and Prussic acid (hydrocyanic acid)—the lethal chamber. Dr. Allan McLane Hamilton was a prominent alienist and forensic specialist (and a descendant of Alexander Hamilton), who had worked in the treatment of nervous diseases and experimented with a number of innovative approaches including electrotherapeutics and the use of nitrous oxide. He told the state panel he favored the lethal chamber. It was his idea to sentence a prisoner to be put to death in a certain week, without specifying the precise date. Unbeknownst to the condemned, in advance of the execution, the condemned prisoner's cell would be "hermetically sealed" and fitted with pipes leading to a furnace or engine. Prison authorities would quietly pump in carbon dioxide or carbon monoxide while he was asleep. The unsuspecting convict would never awaken, thereby being spared all the horrid fear and pain of an ordinary execution. The witnesses would avoid the usual distasteful public spectacle, and justice would be done.[26]

Hamilton's idea did not catch on at first, in part because not everyone was convinced that the new gas technology was up to the task. The Commission rejected the proposal for the lethal chamber in favor of calls for electrocution, although the site of the executions came to be called the "death chamber" rather than the gallows.[27]

In 1899 a prominent New York physician and eugenics advocate, Dr. W. Duncan McKim, pushed again for gas euthanasia, calling it the "surest, the simplest, the kindest, and most humane means for preventing reproduction among those whom we deem unworthy of this high privilege," claiming it would result in "a gentle, painless death." McKim directed his plan at "the very weak and the very vicious, who fall into the hands of the State, for maintenance, reformation, or punishment"—idiots, imbeciles, most epileptics, insane or incorrigible criminals, and a few other classes. To eliminate them, he recommended carbonic gas (also known as carbonic acid gas or carbon dioxide, the gas that had been widely used to euthanize animals.)[28] At the time, McKim's view was widely praised in the United States but not implemented. Then in 1916, during the First World War, Dr. Hamilton published a widely read memoir in which he favored gas as the "most humane alternative."[29]

The first serious effort to incorporate lethal gas into law occurred in early 1921, when Frank Curran, an aide to U.S. Senator Key Pittman of Nevada, suggested substituting lethal gas as the "most humane" way to end life, particularly if it could be administered when the condemned was asleep or sedated under the influence of a soporific drug.[30] Curran convinced two Nevada state assemblymen to introduce appropriate legislation. The bill ended up on the desk of Governor Emmet D. Boyle, a liberal Democrat and mining engineer from Virginia City.[31] On March 28, 1921, Governor Boyle signed the Humane Execution Bill, making Nevada the first state in the world to require the administration of lethal gas to end human life legally.[32]

The new law provided for a suitable cell for inflicting the penalty where gas was to be used and specified that the warden, a competent physician, and six other citizens must witness the execution. The news wire reported, "It is planned that when the condemned man is asleep the air valves shall be closed and others, admitting lethal gas, be opened, life being taken without the prisoner awakening."[33]

At that time Nevada had the smallest population of any state, but its innovation received wide publicity. An editorial in *The New York Times* commented, "The electric chair is not modern enough for the Nevadans, apparently, or else it displeases them in some way, and their law calls for the use of putting condemned murderers to death in what is called in euphemistic terms a 'lethal chamber'—a room that can be made airtight and into which at will can be introduced through hidden conduits a suffocating gas."[34] Nevada's lethal gas approach provided further dramatic testimony in support of Amos Fries's vision: gas would act as a powerful deterrent to America's public enemies, while serving as the "most humane" weapon of war yet devised.

A few months later, Nevada prosecutors selected their first case under the new law. They charged two Chinese immigrants, Hughie Sing and Gee Jon, with capital murder for shooting a Chinese man in Mina.[35] The case occurred during a period of intense discrimination against Asians, known as the "yellow peril" hysteria. A state court affirmed the convictions and held that execution by lethal gas did not violate the constitutional ban on cruel and unusual punishments.[36]

Prisons officials converted the institution's granite barbershop into a death house. The single-story building was eleven feet long, ten feet wide and eight feet high, with a single glass window on each side and an oval one in the back, with two windows and a door in front. It was simply a harmless-looking concrete shack with a small tank and a tangle of pipes against one wall and an exhaust fan on the roof.[37] But it would do well enough.

Professor Sanford C. Dinsmore, a chemist who was the Nevada food and drug commissioner and a former aide to the Army's U.S. Surgeon General, advised the prison board as to what specific brand of poison gas and apparatus should be used. Dinsmore said he selected hydrocyanic acid gas because "it is the deadliest poison known" and would be "instantly fatal" if respired. Dinsmore said he had personally conducted plenty of fumigating operations, and he professed to be well acquainted with the gas. A state spokesman described it as being invisible and lighter than air, saying it would paralyze any condemned man's respiratory organs, displace all of the oxygen in his body and cause instant, painless death after one deep breath. Witnesses would be spared any painful outcries. The initial plan called for lethal gas to be piped from metal cylinders to the floors of two airtight cells. Each cell was to have a glass observation window. The gas would quickly spread to all parts of the cell, rise to the ceiling and eventually be discharged through a pipe that would be high enough to prevent any injury to the witnesses.Three cylinders of gas and two cylinders of compressed air would be used. At the warden's signal, five guards would open the respective valves, each with the option of believing that his tank contained the harmless substance, thereby saving anyone from any feelings of guilt.[38] From the start, the designers anticipated carrying out multiple gas executions using cyanide gas.

On January 30, 1924, General Fries's aide in Washington reached out to Nevada's attorney general regarding the state's plan to execute "certain criminals" by lethal gas. "As this is in line with the work of the Chemical Warfare Service," Major Charles Alley wrote, "it is requested that a report of these executions, covering the kind of gas used, the method of its application, and the physiological effects as noted by the physicians in attendance, be furnished."[39] As the execution date drew near, the death sentences of Hughie Sing and a Mexican-American convict were commuted, but Gee Jon was doomed.

At the time, liquid cyanide (known commercially as cyanogen) had only one distributor west of the Mississippi,the California Cyanide Company—a firm that had recently been started by the Air Reduction Company owned by Percy Rockefeller and headed by Frederick A. Braun, the longtime West Coast agent for Roessler & Hasslacher—which produced quantities of it for killing parasites in the California citrus groves.

Dinsmore determined that the gas, which was run into heavy steel cylinders about 30 inches high and 11 inches in diameter at a temperature low enough to liquefy it, had to be transported in the cylinders under heavy pressure. which is created after the tanks are taken from the brine solution used to cool them when the gas is being liquefied. Due to HCN's hazardous susceptibility to temperature changes, however, the Los Angeles-based California Cyanide Company refused to deliver any of its product to Carson City, and no railroad or express service would carry the dangerous chemicals. Therefore, the state would have to handle its own transport.[40] Dinsmore arranged with the company to purchase a sufficient amount of the liquid cyanide for multiple executions.

Authorities described the "agent of death" as a mobile fumigating unit known as an "autofumer," costing $700 and equipped with tanks of hydrocyanic acid gas. Company officials said the autofumer could kill a person within 30 seconds, or in two to three minutes if the gas was dispensed directly from the tanks, when the liquid vaporized.[41] Once the state agreed to sign a waiver protecting the company from any liability, the firm promised to provide a gas expert who would be available on site to ensure that the equipment was properly installed and in good working order for the execution.[42]

Warden Dickerson sent his most trusted assistant, Tom Pickett, to drive the hundreds of miles to Los Angeles and back to Carson City to pick up 20 pounds of the dangerous gas. Pickett took his wife along in the truck, loaded it with several tanks of deadly HCN, in liquid form, and carried it rolling over rough, icy, mountainous back roads to the prison, in what must have been a harrowing ride. Luckily, the volatile cargo did not explode or leak.[43]

State officials and consultants then tested the death-dealing equipment in their lethal chamber. Four Nevada prison guards resigned from their jobs rather than participate, saying they "didn't want to take a chance on being mixed up in it."[44]

Gee Jon's execution day was set for February 8, 1924. The weather turned out to be humid and cold—hardly a surprise for that time of year. Among the 30 witnesses who attended were representatives of the U.S. Army, public health officials, and numerous reporters.[45] The witnesses crowded close around the window as the guards strapped Gee into his chair and sealed the doors. The gassing commenced at 9:40 A.M.[46]

Hydrocyanic acid vaporizes at 75 degrees Fahrenheit. But the air temperature outside the execution chamber was only 49 degrees, and a faulty electric heater had raised the level to only about 52 degrees, leaving most of the HCN to accumulate in a liquid pool on the floor beneath the chair. So its lethal power was greatly reduced.[47]

Gee's terrified face took on a startled expression and he threw his head back and filled his lungs with the first of the gas to reach him. Witnesses could hear his labored breathing. Then his chin dropped to his chest. A tense moment passed before he threw his head back and took another breath. Again, his chin dropped to his chest. The reporters were recording every movement they could detect.

Some spectators thought they detected the deadly gas, with its fragrance like almond blossoms, and a few of them lurched back from the window in terror, but the warden, the newspapermen, and most of the physicians remained at their posts, oblivious. Two long minutes passed before someone finally whispered, "He's unconscious." Then Gee's head pulled back and his mouth opened, showing his teeth. His eyes rolled back until his pupils disappeared and his head jerked forward.

"He's dead now," one physician said, leaving the spectators to scour Gee's body for any movement, any sign of life, for a whole minute without spotting any. But then Gee raised his head again and extended it all the way back, causing many of the onlookers to gasp in horror. His chin dropped again and rested on his chest. The witnesses stared as closely as they could, but nobody saw any stirring. The gas clouding the window made it difficult to see inside the chamber very well, but it appeared that Gee had not ceased to move until 9:46 A.M.—after 10 full minutes. At last, he remained motionless.

The warden ordered all witnesses to leave the prison yard. After they had gone, at 10 o'clock, the ventilator gate was opened, and the suction fan was turned on. For safety purposes, the chamber was kept closed for more than two hours.[48]

Prison staff finally removed the body at 12:20 P.M. and carried it to the prison hospital, where they placed it face-up on a table. A group of seven physicians briefly examined the corpse and officially pronounced him dead, but they did not conduct an autopsy out of fear that it might release some deadly gas.[49]

Reaction to the execution was mixed. One correspondent reported, "Those who witnessed the first lethal gas execution here Friday were unanimous in declaring that if they had to suffer capital punishment they would prefer to die that way."[50] Nevada's biggest newspaper, the *Nevada State Journal*, pronounced: "Nevada's novel death law is upheld by the highest court—humanity."[51] But the *San Jose Mercury Herald* warned, "One hundred years from now Nevada will be referred to as a heathen commonwealth controlled by savages with only the outward symbols of civilization."[52] *The New York Times* noted that a white man had been spared at the last moment, "and the new method was tested on a Chinaman," adding: "That will need a good deal of explaining."[53] The *Philadelphia*

Record called it the worst piece of official barbarity since the Dark Ages, and the New Haven *Journal-Courier* observed: "Nevada is the first state to take human life by this means, and we hope it will be the last."[54]

Warden Dickerson reported to Governor Scrugham: "This method of execution, while no doubt painless, is not, in my judgment, practicable." He thought its use posed too many problems. It required an expert in handling the gas, which complicated matters for prison officials. Cyanogen gas was also highly volatile and had to be kept at a low temperature to prevent explosion. Its rapid deterioration made it impracticable to keep a supply on hand, and it was hard to obtain. Because express companies refused to handle it, the chemical needed to be carried by private conveyance from Los Angeles, which was a hazardous undertaking, especially during the summer months. Leaks in the death house were hard to detect. Most of all, he was afraid of its danger to staff and bystanders. In short, there were many technical problems still to be worked out if gas executions were going to continue.[55] Dickerson's judgment carried special weight because he was so widely respected.

As Nevada authorities searched for ways to improve their gas-chamber executions, the U.S. Public Health Service (PHS) conducted tests to investigate different ways of using cyanide gas. From August, 1929, to February, 1930, agency scientists conducted lethal experiments in a tightly sealed, unheated room measuring about 500 cubic feet at the San Francisco Quarantine Station on Angel Island. Located next to the station's laboratory, the chamber had special apertures that enabled the technicians to introduce live roaches and chemicals into the room without opening the door. Through a peephole the researchers observed the effects of various gases upon the live subjects. In 13 tests, "Zyklon-B in the proportion of 60 gm. per 1,000 cubic feet for one hour of exposure was found most effective" in killing all the subjects. The researchers also found Zyklon most effective at warmer temperatures and at cooler temperatures close to freezing.[56] Another PHS report commented, with eerie foreshadowing, "Leaving the cumbersome, laborious, and time-consuming sulfur fumigation, we have passed through the method of generating HCN, with its still cumbersome apparatus and paraphernalia, through the period of liquid HCN, complicated by the difficulty of transporting so dangerous a material, and have arrived at the exceedingly simple procedure of knocking a hole in a can of Zyklon, pouring the contents down the hold, and throwing the can overboard."[57]

Although the PHS reports referred only to bugs, researchers realized they had other implications. Scientists had become increasingly aware that cyanide was actually *more effective* on warm-blooded animals such as human beings than on insects, because vertebrates carry oxygen in their blood via hemoglobin, whereas insects' blood does not carry oxygen. Humans absorb cyanide gas through the lungs, gastrointestinal tract, and skin (especially including the mucous membranes and eyes). Unprotected exposure and breathing in an enclosed space of hydrocyanic acid, particularly Zyklon-B, would therefore be extremely deadly to people. However, the proof of that would have to be left to prison authorities to determine.

The late 1920s had witnessed some intense jockeying among the major chemical firms for more control over the world cyanide market, sometimes pitting German against American interests. American Cyanamid was on the rise, and in 1930, Roessler & Hasslacher was purchased by E. I. DuPont de Nemours & Co., Inc., the immensely powerful American corporation. During the early 1930s the giant chemical firms—DuPont, American Cyanamid, DEGUSSA, and Imperial Chemical Industries (ICI) of Great Britain—would continue to play the cyanide cartel game, sharing technical expertise, dividing markets, and fixing prices, enmeshed so closely that it was often difficult to tell them apart.[58]

The 1930s marked a period of gradual industrial refinement and expansion of the American gas chamber. Following Nevada's improvements, Arizona and Colorado enacted laws to switch from hanging to lethal gas. Colorado hired a small Denver firm, Eaton Metal Products, to design and construct a leak-proof apparatus resembling a diving bell, which would remove the risks to staff and witnesses, while ensuring maximum effectiveness.[59] Eaton was a leading steel plate fabricator that manufactured grain bins, pressurized tanks, and other structures; it also had experience in working with cyanide, by virtue of its metal processing work. For Eaton, the Colorado gas chamber prototype would turn out to be a signature specialty item that would enable the company to enjoy worldwide dominance in that line of products for several years to come.[60]

Colorado and Arizona conducted their first multiple executions. They also put to death some convicted criminals who were classified as mentally retarded. North Carolina also adopted lethal gas as its official method of execution, and hired Eaton to build its chamber. The overwhelming majority of those it put to death were black. Wyoming and Missouri each instituted their Eaton gas chambers in 1937, and California followed two years later. The California model was Eaton's fifth. A company official proudly noted that the latest version incorporated the newest innovation in death cell manufacture. In the past, acid had been placed in an ordinary crock under the death chair and the potassium cyanide eggs were dropped into it by pulling a lever. But under the new system, acid would simply be let into the chamber through special tubes. The new system was intended to make it easier for the executioner. "Pulling a lever to kill a man is hard work," the designer explained. "Pouring acid down a tube is easier on the nerves, more like watering flowers. But it gets results."[61] Eaton's patent was filed with the U.S. Patent Office on October 16, 1937, and a patent was issued two years later.[62] Oregon followed in California's footsteps, and by 1940, eight American states had adopted lethal gas as their official method of execution. (The last of 594 American gas chamber executions was carried out in 1999.) American ingenuity had worked out the gas chamber's basic technical issues.

Chapter 7

The Attack That Never Came

By the late 1930s the growing likelihood of another world war was fanning fears of a chemical warfare apocalypse. Worrying that the warring powers would pick up where they had left off in 1918, many people could not help but note that the lines between civilian and combatant seemed to have disappeared, as evidenced by alarming reports about Benito Mussolini's spraying of mustard gas on Ethiopians in Abyssinia, Francisco Franco's air attacks on Guernica and other cities in the Spanish Civil War, and Japan's use of poison gas and other atrocities against China.

As many turned their attention to civil defense, gas masks, and evacuation plans, a leading voice for preparedness was J. B. S. Haldane, the distinguished Cambridge physiologist and geneticist, who was known as one of Britain's most popular and controversial scientists. In 1925 he had published a widely read essay, *Callinicus: A Defence of Chemical Warfare*, in which he sought to quell rather than precipitate rising fear over the new terror weapons and tactics spawned by the Great War. Then, as another world war appeared imminent in 1938, Haldane aimed to address what seemed a much more immediate threat of aerial bombardment of cities that might be coupled with the use of poison gases. He published a brave new book, *A.R.P.* (short for "Air Raid Precautions"), hoping to "save the people of Britain from the fate which is now befalling the peoples of Spain and China." In it he presented some of the nuts and bolts of chemical warfare—and argued that the British people could survive it and triumph if they did not succumb to fear.

Haldane was a Marxist who had been wounded in World War I, and he was not one to mince words. First of all, he said, England needed to try diplomatically to keep air bombers away, at least until the nation could establish an adequate civil air defense. This also meant improving military intelligence, marshaling defensive airplanes, utilizing blackouts, installing searchlights and antiaircraft guns, building air shelters, and educating the general public about how to protect itself during an attack. He also minimized the dangers associated with various poison gases, telling citizens what to do if they were targeted. The world watched as Britain took his advice and prepared for a possible gas attack.

Even in the continental United States, isolated on each side by a vast ocean, prewar worries about such an assault put many people on edge.[1]

Americans' susceptibility to panic was dramatically demonstrated shortly after 8 P.M. on October 30, 1938, as residents in Newark evacuated their houses with wet cloths over their faces, and ambulance crews raced to assist victims of a reported chemical bombardment. A Pittsburgh husband came home to find his wife cringing in the bathtub, clutching a vial of poison and screaming, "I'd rather die this way than like that!" Across the Deep South men and women knelt down in the streets and prayed for deliverance. In San Francisco, an agitated caller reached the police to say, "My God! Where can I volunteer my services? We've got to stop this thing." The nationwide hysteria occurred in response to a radio report that objects initially believed to be meteors had crashed down near Trenton, New Jersey, killing many people. Later bulletins announced that the meteors were monsters from Mars, spreading death and destruction by torch and poison gas.[2]

The listeners were tuned to CBS radio, where Orson Welles and a tiny troupe of actors known as the Mercury Theater of the Air had taken the microphones in New York to present a freely adapted version of H. G. Wells's classic science fiction novel, *The War of the Worlds*. The script made for some gripping radio. But in reality, there *was* no poison-gas attack from outer space; the show was simply a devilishly realistic dramatization of a famous fiction. Most listeners did not know that, though; they believed their ears, accepting as gospel what they heard over the airwaves, and this had caused a panic. The "War of the Worlds" radio program struck a nerve due to what was happening in the world at that time. Hitler's invaders had recently seized the Sudetenland from Czechoslovakia, and Americans had been hanging on their radios for on-the-spot coverage about more possible invasions; some of their worst fears were of a poison gas attack by Germany, Italy or Japan—the kind of warfare they expected in the next world war.[3] Based on the panic that ensued in the United States, observers in Japan and Germany were left to conclude that Americans were both terrified of an attack and ill-prepared for war.

American newsreels soon showed London housewives wearing gas masks as they tended their baby carriages, and after Pearl Harbor was attacked there were images of children in Hawaii carrying gas masks to school.

American public opinion strongly rejected the use of chemical weapons, and every U.S. president since Warren Harding had pledged to abide by the 1925 Geneva Protocol outlawing their use. Once the nation was at war, however, American defense policy was built on deterrence and threats to retaliate in kind if necessary.[4] Wartime industry went into high gear, and civil defense was bolstered. But Americans were not eager for another chemical war.

What Americans were unaware of was that Hitler did not favor chemical warfare either. Heinrich Himmler had offered a plan for waging gas warfare, but Germany's Führer did not approve it because he feared how the enemy would react and also because he had experienced gas warfare himself in the last war and felt that its use on the battlefield was unjustified.[5] Thus, contrary to what many had expected, during the early days of World War II there were no chemical warfare attacks at all,at least not yet. But keeping such weapons in check would require a delicate balance.

For much of his career, Britain's Prime Minister Winston Churchill had been a staunch advocate of gas, and after reading intelligence reports that Germany was preparing to launch gas warfare against Russia (then a British ally), on May 10, 1942, he warned Hitler in no uncertain terms that Britain would retaliate with gas "in kind and in full measure" on German cities if that transpired.[6]

President Franklin D. Roosevelt, on the other hand, was personally opposed to using gas as a matter of principle. But he was worried that Japan as well might resort to chemical attacks on Americans. On June 5, 1942, Roosevelt warned Japan (and hence its Axis allies): "If Japan persists in this inhuman form of warfare against China or against any other of the United Nations, such action will be regarded by this Government as though taken against the United States, and retaliation in kind and in full measure will be meted out."[7] Three days later he went further by saying, "Use of such weapons has been outlawed by the general opinion of civilized mankind. This country has not used them, and I hope that we will never be compelled to use them. I state categorically that we will under no circumstances resort to the use of such weapons unless they are first used by our enemies."[8] At the same time, however, Roosevelt increased the resources of the Chemical Warfare Service, from an appropriation of $1.5 million and 500 personnel before the war to a budget of $1 billion and more than 60,000 personnel in 1942.[9]

Germany, Japan and other powers effectively did the same, holding back their chemical weapons until and unless the enemy used them first, while at the same time escalating their war gas research and chemical production.

But while all sides continued to refrain from initiating a first-strike use of poison gas, there were several points during the war when such restraint grew thin. Germany had secretly developed more deadly new gases (nerve agents) and held the production advantage with poisonous gases throughout most of the war. But the Germans could not be sure of their lead in the chemical arms race, and on May 15, 1943, Hitler asked IG Farben's Otto Ambros if there were sufficient stores of his new wonder weapon gas to use against the advancing Russian army. Ambros told Hitler that production was increasing, but he suspected that the Allies had developed nerve agents of their own, since such chemicals had been discussed in international trade journals before the war. Ambros fretted that the combined Allied forces would be able to out-produce Germany when it came to poison gases, and therefore, given the greater vulnerability of German cities to Allied aerial bombardment, he thought it did not suit Germany's interests to start gas warfare. (As it turned out, some of his assumptions were mistaken, in that the Allies had not yet developed nerve agents.)[10]

The Germans were not the only ones who came close to using chemical weapons. The Allied invasion of Italy that got underway in late 1943 featured an incident, hushed up at the time, which dramatized some of the unforeseen consequences of the chemical arms race. Early in the morning of December 2, 1943, a fleet of Allied supply ships were moored in the Bari harbor in southern Italy when a squadron of German planes attacked several of the anchored vessels. The U.S. Liberty ship *John Harvey* received a direct hit that blasted its contents into the air and water all around the harbor. Hours after the raid, wounded survivors were pulled to safety, but the next day they and many of the rescuers were diagnosed with mustard-gas poisoning. Eighty-three military personnel died, and 600–1,000 were blinded or burned; on shore, close to 1,000 civilians also perished. The Bari air smelled like garlic, and angry rumors spread that the Germans had used poison gas. Nobody dared to admit that the *John Harvey*'s cargo of 2,000 bombs had contained sulfur mustard gas. The Allied high command initially tried to cover up the disaster, worried that a revelation might provoke the Germans into using some of their own gas in response. Allied strategists pondered their options.

The Chemical Warfare Service and other elements within the U.S. military repeatedly tried to convince FDR to allow the use of gas in the Pacific. In December 1943, after the bloody Battle of Tarawa demonstrated the willingness of Japanese forces to fight fanatically to the death, Maj. Gen. William N. Porter, chief of the Chemical Warfare Service, urged the Army to utilize chemical weapons as a way of averting heavy American casualties. Several major newspapers picked up the call for the United States to gas Japan, and the *Washington Times-Herald* declared, "WE SHOULD HAVE USED GAS AT TARAWA . . . YOU CAN COOK 'EM BETTER WITH GAS."[11]

But FDR and three-quarters of the American public still opposed initiating chemical warfare, particularly since there was still great concern about the Nazis' capability to introduce some new gas wonder weapon. The greatest threat occurred around the Allied invasion that started at Normandy in June 1944. The Germans probably could have stalled the invasion by employing gas. But once again, to the surprise of many Allied commanders, Hitler held back from unleashing his chemical weapons. The D-Day invaders were able to gain their foothold.

In mid-June 1944, however, Germany attacked England with V-1 rockets, killing 2,700 people, injuring 10,000, and damaging the homes of more than 200,000 English civilians. The new weapons carried only conventional explosives. But if the V-1s or their successors, the V-2s, had been armed with nerve agents, the effects would have been much worse. Hitler had nerve agents at his disposal. But for reasons that baffled some of his adversaries, he had not exercised that option—yet.[12] But British intelligence warned that might change. Fearing that chemical warheads were next, Churchill fumed to his advisors that he wanted to "drench the cities of the Ruhr and many other cities in Germany [with gas] in such a way that most of the population would be requiring constant medical attention. . . . I want the matter studied in cold blood by sensible people and not by that particular set of psalm-singing uniformed defeatists which one runs across, now here, now there."[13]

But cooler heads prevailed. The British reasoned that gas warfare would divert precious aircraft from their most effective strategy of destroying Germany's vital war industries. They concluded that, instead of proving decisive, chemical attacks would likely provoke the madman Hitler into retaliating against England with even greater force; he would also gas Allied prisoners of war (just as he had already being doing against the Soviets and the Jews).[14] Therefore, there was no chemical attack on the Ruhr.

Although Hitler remained reluctant to use chemical weapons in combat, by mid-1944, it was known that Germany was using gas chambers on a massive scale in an effort to exterminate European Jewry. Many observers felt something had to be done to stop it. On September 16, 1944, the Hebrew Committee of National Liberation urgently appealed to the Allies to intervene. The committee cited Roosevelt's previous statements threatening chemical warfare retaliation against the Axis powers if they used "poison gas against civilian or military populations . . . of any of the United Nations." The group wanted the Allies to threaten Hitler that "unless the practice of using poison gas against the Hebrew people ceases forthwith, retaliation in kind will be immediately ordered against Germany."[15]

But the Allies held back from making such threats. Ultimately, the U.S. government declined to raise a finger in response other than to continue trying to win the war. Neither did the British. The Allies did not target Auschwitz-Birkenau or its rail lines; they did not eliminate the German chemical factories, or send in sabotage teams to destroy the death camp apparatus, or threaten Hitler with drastic reprisals. For Germany, the end was fast approaching, yet the Allies' unwillingness to stop the genocide left Hitler free to continue gassing the Jews, which he did.[16]

Nevertheless, the chemical option still remained. In January 1945, the Führer ordered stores of his nerve agent tabun loaded into barges on the Elbe and Danube rivers in preparation for a final counterattack, but the assault was never launched.[17] In February 1945, the Allies resorted to a form of chemical warfare when British and American planes blanketed the medieval city of Dresden with incendiary bombs—explosives that were packed with highly combustible toxic chemicals such as magnesium, phosphorus and napalm, which were designed to incinerate everything in their path. The inferno killed 35,000–100,000 Germans, most of them civilians. The Nazis were incensed. Goebbels urged the Führer to use gas in retribution. The Allies feared they might be in for a last-ditch chemical fight.

Just as Hitler was considering his options, the U.S. Joint Chiefs of Staff delivered to the Germans a statement acknowledging the Bari accident but emphasizing that the United States did not intend to use poison gas except in retaliation after a German chemical attack. Once again, Hitler held back with his nerve agents; full-scale chemical warfare was again averted.[18] The Allies refrained from using mustard. Within weeks, Allied troops captured Germany's abandoned poison gas production plants and personnel, thereby ending the Nazi threat.

Germany's defeat on May 8 focused attention on the Japanese, who were thought to have very little remaining chemical warfare capability. America's stated policy in 1945 continued to be that it would resort to gas only in retaliation for a Japanese first use. But behind the scenes America's military leaders were seriously weighing a major gas assault, along with every other tool at their disposal. The Army secretly tested chemical weapons against caves and underground fortifications and found them quite effective.[19] With expectations running high that Japanese forces would resist to the death, pressure mounted on U.S. commanders to "turn on the gas" in order to save American lives. Many top commanders remained unaware of the additional option of the atomic bomb.

In June 1945, a top-secret report by the U.S. Army's Chemical Warfare Service (which was not made public until July 1991) presented plans for a massive preemptive poison gas attack as part of the Japan invasion. Tokyo and 24 other targets were singled out as "especially suitable for gas attacks." The Americans expected the Japanese to defend their home islands fanatically, and gas offered a less costly way to defeat them, according to the CWS. "Operation Coronet," scheduled for March 1946, would entail large-scale gas assaults using phosgene, mustard gas, and hydrogen cyanide. The study declared: "Gas attacks of the size and intensity recommended on these 250 square miles of urban population might easily kill 5,000,000 people and injure that many more."[20]

In some ways Operation Coronet resembled an update of the chemical warfare attack plan that had been hatched for 1919. In terms of civilian casualties, even the bombing of Hiroshima and Nagasaki would turn out to be less severe in comparison to the chemical onslaught favored by many Army brass. The Army chief of staff, Gen. George C. Marshall, favored using gas in such a manner, even though he opposed introducing the atomic bomb. Although Gen. Douglas MacArthur had been gassed himself in World War I, he was not hesitant to use it to kill millions of civilians; the supreme commander in the Pacific said he could see "no reason why we should not use gas right now against Japan proper. Any kind of gas." Assistant Secretary of War John J. McCloy also favored reconsidering the gas option "in the face of the public pressure for the use of gas, which may develop as our casualties rise due to the Okinawa cave type of Japanese defense."[21]

With the invasion looming, it appeared that the United States was likely to go the chemical route. The CWS gas attack plan, approved by Major General William N. Porter, was discussed with President Harry Truman on June 18, 1945. The Army immediately moved to step up production of several types of poison gas in order to meet the terms the plan required, and preparations were also made to utilize some of the seized Nazi stockpiles for use against the Japanese. As envisioned, the gassing approach called for a wholesale slaughter of "enemy civilians to a level far beyond anything seen yet in World War II."[22]

In the end, the gassing of millions of Japanese civilians was avoided when Truman decided to drop the atomic bomb instead, thereby forcing the Emperor's surrender and ending the war. Thus the conflict that everyone had expected would be dominated by chemical weapons turned out to be one in which gases were never used against the enemy on any battlefield. But the Nazis used poison gas to murder millions of innocent civilians, and American commanders came close to using it to kill millions more Japanese.

Chapter 8

Holocaust: Carbon Monoxide, Zyklon-B Hydrogen Cyanide

In the First World War, then Lance Corporal Adolf Hitler had seen some of his comrades die from poison gas; one of them was a panicked young soldier who had ripped off his mask and inhaled a toxic cloud that left him gasping and dying a few feet away. Near Wervicq in Flanders on the night of October 13–14, 1918, Hitler himself was gassed with British mustard and temporarily blinded. "My eyes had turned into burning coals," he later wrote.[1] The next day, unable to stand, he was taken to the hospital. He was still recuperating on November 10 when a priest came by to announce that Germany had agreed to surrender.

Based upon his personal experience, Hitler always harbored a deep hatred of chemical warfare, and this may help to explain why he refused to authorize the use of poison gas against combatants on the battlefield. At the same time he ordered his army to develop a massive arsenal of new chemical weapons, and his forces used lethal gases to murder millions of helpless Jewish men, women and children civilians in euthanasia centers, mobile killing units, and concentration camps, in an effort to exterminate an entire "race."

Hitler fashioned the ideological and practical foundation for using gas in the Final Solution by realizing the extreme logic of radical eugenics. Shortly after he came to power, in March 1933, he had Germany enact a law calling for compulsory sterilization for persons with a range of infirmities thought to be hereditary, such as mental illness, epilepsy and imbecility. This was only the first step in carrying out what he and his followers called the principle of "life unworthy of life" (*lebensunwertes Leben*). In 1935 he confided that "in the event of war, [he] would take up the question of euthanasia and enforce it," since he knew that "such a problem would be more easily solved" during wartime. From the start, he planned to use war as a pretext and a cover for killing all of the "unfit."[2]

In early 1939 Hitler took another step toward this goal by ordering his personal physician and a member of his inner circle, Dr. Karl Brandt, to travel to Leipzig to grant the request for a government-sanctioned "mercy killing" that had come from the parents of a blind and deformed boy.[3] The moment the war was underway, the Führer issued a formal directive, decreeing that Brandt and Reichsleiter Philipp Bouhler (chief of Hitler's Chancellery) "are charged with the responsibility of enlarging the authority of certain physicians to be designated by name in such a manner that persons who, according to human judgment, are incurable can, upon a most careful diagnosis of their condition of sickness, be accorded a mercy death."[4]

Once the Nazis had legitimized the concept of "life unworthy of life" and formulated a policy of medicalized killing, they went on to broaden its meaning and remove the safeguards. In late 1939, they inaugurated the "euthanasia program," code-named "T4" after its main address at the Chancellery at 4 Tiergartenstrasse. Designed to be carried out in six mental institutions scattered throughout Germany, the first "mercy killings" were to be administered under the aegis of the Reich Committee for the Scientific Registration of Serious Hereditary and Congenital Diseases. Midwives and physicians were required by law to report newborns and young children who were diagnosed as showing signs of idiocy, mongolism, microcephaly, hydrocephaly, malformations or paralyzing conditions. A panel of three outside medical experts would then decide who among them should live and who should die.

At Brandenburg State Hospital and Nursing Home in January 1940, the Nazi doctors experimented with a variety of killing methods. Brandt and Leonardo Conti (the Reich Minister for Health) personally administered the first lethal injections, trying out various combinations of painkillers and poisons including curare and Prussic acid. But the shots did not go well: many patients did not die very quickly or easily, and sometimes the procedure had to be repeated due to failure to reach a vein and other factors. Worst of all, the injecting required a physician and other medical personnel to come into very close physical contact with a person in order to kill him or her. Afterwards a physician would sign an official letter to the victim's family, falsely reporting that their relative had died of pneumonia or some other natural cause.[5]

Gas, on the other hand, proved easier to use. For the T4 teams working in the psychiatric hospitals, the easiest part was to create the gas chamber itself. As later described by Bouhler's assistant: "No special gas chambers were built. A room . . . attached to the reception ward . . . was made into a gas chamber. It was sealed, it was given special doors and windows, and then a few meters of gas pipe was laid, some kind of pipe with holes in it. Outside of this room there was a bottle, a compressed bottle, with the necessary apparatus, necessary instruments, a pressure gauge, etc."[6] At first, the logistical approach resembled in some ways what had been done 16 years earlier in the Nevada State Prison. But the Nazis were already operating on a broader scale.

An SS chemist, Dr. August Becker, had obtained canisters of pure carbon monoxide from BASF, the IG Farben factory at Ludwigshafen. The poison had the potential for multiple executions and did not require medical personnel to kill each person one-by-one on an intimate, individual basis. They did not even have to get close to the victims. Everyone would die by asphyxiation.[7]

Under the new procedures that were tried out, a "nurse," who was really an SS chemist (Becker), led 18–20 naked male patients into a newly constructed "shower room" under the pretext that they would receive inhalations for therapeutic purposes. (Bouhler was later credited with the fake shower idea.) The T4 technicians demonstrated their procedure before an approving audience of selected high-ranking Nazi officials, most of whom were physicians, chemists, or police. Once the quivering patients were inside the chamber, the door was shut. An SS chemist (Dr. Albert Widmann) piped in the lethal gas, as Becker looked in through a peephole to see that "people toppled over, or lay on the benches"—all without any "scenes or commotion." Each victim reportedly collapsed within one minute. After another five minutes the room was aired. Then SS personnel used special stretchers to mechanically remove the bodies and shove them into a crematorium furnace. There were no medical checks or autopsies.[8]

The gassing team made refinements as they went along. During one demonstration, Becker noticed that Brandenburg's director, Dr. Irmfried Eberl, had opened a highly pressurized gas container in such a way as to cause the escaping carbon monoxide to make a disturbing hissing sound. Therefore, in an effort to avoid any noise that might unsettle anyone, Becker demonstrated how to open the valve slowly and quietly, so the execution could proceed more smoothly.[9]

When it was done, Brandt and Viktor Brack (Bouhler's first assistant) expressed satisfaction that the experiment had gone so well. At first, Brandt insisted that "only doctors should carry out the gassings." Even though as a physician himself, he did not like the idea of gassing because, as he would later explain, "In my medical imagination carbon monoxide had never played a part." But he was able to comfort himself by recalling a personal experience he had had with carbon monoxide poisoning in which he had lost consciousness "without feeling anything." This reminder eased his mind enough to allow him to conclude that the gas would be "the most humane form of death" for euthanasia purposes. After the experiments were completed, the time came to report the results to Hitler. When Brandt explained the different arguments for the two methods, the Führer pointedly asked, "Which is the more humane way?" Brandt then replied that the answer was clear. It was gas. His chief deputy, the zealous Nazi psychiatrist SS-Hauptsturmführer Dr. Werner Heyde, was so enthusiastic about the euthanasias that Hitler appointed Heyde as T4's medical director. From that point, the gassing program was off and running.[10]

The first Nazi gas chambers were small, sealed structures that had been converted, like Nevada's stone barber shop, for carrying out executions. Soon they were operating at full tilt, processing several persons at a time and thousands of subjects in all. Their targets were no longer limited to incurables. Now the concept of life unworthy of life had been expanded to include certain healthy persons as well: Jews, Gypsies, and other undesirables. The Nazis had also taken a page from the earliest American conceptions of a death-dealing cell that would catch its victims unaware–before they knew what was happening. Instead of piping the gas into an inmate's prison cell as he slept, as some Americans had originally suggested, the Germans opted for a fake communal "shower room" that would require the victims to become naked and even more helpless; the subjects' nakedness would also facilitate the lethal effects of the gas, since the poison would be more readily absorbed by their warm, exposed skin.

Herbert Kalisch, an electrician from General Electric who was recruited into T4 to help install needed wiring in the gassing devices, witnessed the treatment of Jewish inmates at Brandenburg in June 1940. About 100 women with children and 100 males were rounded up and herded into groups. "The persons were undressed completely, as they were told that they would be taken to another building for bathing and delousing," Kalisch later recalled:

> First they took women and children for gassing. To pacify these patients, physicians gave each of them a cursory examination. Thereafter, they were placed in a room with wooden benches, which looked, more or less, like a shower room. But before they entered the room, they were marked with consecutive numbers. The doors were locked as soon as the prescribed number of persons had entered the "shower room." At the ceiling were showerheads through which gas entered the room. The gas was ventilated after fifteen to twenty minutes, as soon as observers had discovered by looking through the peephole that no one inside remained alive. As the earlier examination had noted which persons had gold teeth, these persons could now be discovered by their marked number. The gold teeth were pulled from the dead people. Thereupon SS men stationed at the prison carried the dead people from the "shower room" and took them to the crematorium. Qn that very day, the entire transport was eliminated in this fashion.[11]

One of the key players assisting in the development of the Nazis' new gassing systems was a tall, broad-shouldered bald man with thick eyebrows and a Hitler moustache. SS-Obersturmführer Christian Wirth was a former Stuttgart policeman (murder squad) and Brownshirt, who often carried a whip that he wielded with savage brutality. After supervising the first gassings at Grafeneck, and working in several of the euthanasia centres in mid-1940, Wirth was appointed as head of the euthanasia program in Germany and Austria.[12]

But the program ran into a snag. In December 1940, word leaked out to the community around Grafeneck Castle that the institution was using automobile exhaust to "euthanize" some of its disabled patients, including decorated veterans from the Great War.[13] Many German citizens were appalled. Himmler the SS chief ordered Grafeneck closed, and after officials of the Roman Catholic Church and British news media publicly complained about the practice, Hitler temporarily suspended the euthanasia program until the scandal subsided. But behind the scenes Wirth and his T4 associates were ordered to redouble their efforts.[14]

After Germany invaded the Soviet Union in June 1941, the nature of the war changed radically, and the Nazis vastly expanded the scope of the population targeted for extermination to include much of the conquered populace from the Eastern Front. Wirth became the organizer of *Aktion Reinhard1*, the secret mass gassing program that was slated for high-volume extermination camps to be built in the Lublin district at Belzec, Sobibór, Majdanek and Treblinka.[15] Named as its inspector, Wirth arrived in Lublin in late October and quickly went to work refining the plans.[16]

Belzec was to be the first death camp completed. It was square in shape and enclosed by a barbed wire fence with watchtowers. Special railway tracks led directly into the camp to deliver freight cars full of fresh victims. Wirth supervised the building of nondescript-looking barracks that were designed to be fitted out as gas chambers. His adjutant, SS-Obertscharführer Josef Oberhauser, oversaw the construction, which was done by Poles from Belzec and then by Jews from ghettos in neighboring towns.[17] Belzec's killing area was set behind rows of conifers and surrounded by an electrified barbed wire fence policed by armed guards with German Shepherds. Camouflage nets were installed to keep it from being spotted by reconnaissance planes.[18]

"Wirth told us in Belzec, 'all Jews were to be bumped off,' " one SS man recalled. "The nozzles were not constructed to a water pipe, because they were only meant to serve as camouflage for the gas chambers. The Jews who were to be gassed were untruthfully informed that they were to be bathed and disinfected."[19]

Wirth had developed expertise in mass killing, which he now sought to implement. Shooting was too slow and cumbersome; it required large numbers of personnel at several locations and was impossible to keep quiet. It could prove hard on the shooters; shooting also invited resistance, flight, and exposure. Therefore gas remained the best way to carry out mass extermination. To generate the necessary poison gases, he considered various options but initially rejected using the pesticide Zyklon-B, because its appearance in large quantities might have aroused suspicion and he was concerned about possible supply problems. At least for the time being, utilizing carbon monoxide would prove easier. For the first tests Wirth used bottled carbon monoxide; then later he would resort to whatever resources he could scavenge, including a 250-horsepower engine that had been taken from a captured Russian tank, the poisonous fumes from which were piped into the chamber.[20]

To carry out their mass gassings, Wirth and his cohorts designed a system to process the new arrivals, whereby the men would quickly be separated from the women and children and led into stations where they would be shaved and made to take off their clothes. Then the naked victims would be rushed through a corridor (the tube) into the "showers" (gas chambers). Then the airtight door would be locked and the engine started. Carbon monoxide gas pumped into the chamber would kill everyone within 20 to 30 minutes, after which the bodies would be removed and buried in mass graves.[21]

As soon as the initial installations were ready, Wirth immediately rushed to put them into operation. Two convoys of freight cars loaded with Jews were used to test out the gas chambers and refine the extermination process as much as possible. Wirth's painstaking and closely monitored tests lasted for several days.

A stickler for speed, he demanded that everything be done with utmost efficiency. The last ones killed in the testing were the Jewish prisoners who had helped build the camp.[22] That way there would be no witnesses.

Full-scale extermination began on August 1, 1942. SS-Untersturmführer Kurt Gerstein of the disinfection service, who observed the processing, was present shortly after 7 A.M. when the first train of 45 freight cars arrived from Lvov. Of 6,700 passengers, one-quarter were already dead. "Terribly pale and frightened children looked out through grille-covered openings," Gerstein later said:

> their eyes full of mortal anguish, and behind them men and women. The train pulled into the station, and two hundred Ukrainians tore back the doors and whipped the people out of the cars with their leather whips. A huge loudspeaker gave out further instructions: Strip completely, artificial limbs, too, and spectacles, etc. Valuables to be handed in at the counter, no receipts or invoices. Shoes carefully tied together (for the collection of spun materials) . . . then the women and girls to the hairdresser, who with two or three hacks cut off all their hair, which then disappeared into potato sacks. "This is for some special purpose for submarines, for caulking or something like that," I was told by the SS-Untersturmführer who was on duty there.

Gerstein noted seeing a pretty young girl leading the procession of naked men, women and children as they moved along the path. Gerstein recalled:

> I was standing with Captain Wirth up on the ramp, between the gas chambers. Mothers holding their babies close to their breasts climbed up, hesitated, and entered one of the gas chambers. A large SS man stood at the corner and said to the unfortunate victims with a voice like a pastor: "Nothing whatsoever is going to happen to you. You must now breathe deeply once you are inside the chambers; this will dilate your lungs; this inhalation is necessary because of illness and disease." When he was asked what was going to happen to them, he replied, "Naturally the men must work, build houses and roads. But the women won't have to work. Only if they want to, they can help with the cleaning and in the kitchen." For some of the unfortunate victims it was a glimmer of hope, enough to get them to take the few steps that led to the chamber without resistance. But the majority knew what it was about: the smell announced their fate. They climbed up the few steps and then saw everything. The women with babies at their breasts, the little naked children, the adults, men and women, all naked–they hesitated, but they entered the death chambers, pushed by those behind them or by the leather whips of the SS men. Most of them said not a word. Suddenly a Jewess of about 40 years old with flaming eyes cried out, "Let the blood spilt here fall on the heads of the murderers." For which Wirth delivered five or six whips to her face with his riding whip as she, too, disappeared into the chamber.[23]

Belzec contained six concrete gas chambers, three on each side of a three-meter-wide corridor. Each chamber had a tiny peephole through which the SS men could watch what happened next. "The Jews went into the chamber quietly and without resisting," one eyewitness, SS-Sturmbannführer Wilhelm Pfannenstiel (a professor at the Hygienic Institute), later recalled.

> It was only when the lights went out that they began to get restless. And at that moment the engine started up. So far as I can remember, the gassing operation lasted a relatively short time. I think I remember looking at my watch and that it took eighteen minutes until no more sound came from the chamber. The inside of the peephole in each door became steamed up relatively quickly, so that nothing more could be seen from the outside. When silence fell, the doors situated on the exterior wall of the building were opened.[24]

It took scarcely more than one year, from March 1942 to the spring of 1943, for the SS to exterminate all of their victims. Then Belzec was closed. Once again, as the Germans left the camp, Wirth had all the Jewish workers gassed or shot. Later the Germans used more Jewish prisoners to exhume and cremate the remains and dismantle all vestiges of the camp. Those Jewish workers were then sent off to Sobibór to be gassed. Belzec's grounds were plowed under and converted to a farm; then trees were planted where the gas chambers had once stood.[25]

Sobibór was the second killing center in the Lublin region to commence operations. It had been built on a similar design, although its six gas chambers were slightly bigger and could accommodate up to 1,200 people. Once the SS had installed the Russian benzene motor and made everything ready, SS-Unterscharführer Erich Fuchs got it running. A chemist carefully measured the concentration of gas in the chamber. Then they carried out a gassing experiment on 30–40 Jewish women. "When the women were shut up in the gas chamber I and Bolender set the motor in motion," Fuchs later recalled. "The motor functioned first in neutral. Both of us stood by the motor and switched from 'Neutral' to 'Cell,' so that the gas was conveyed to the chamber. At the suggestion of the chemist, I fixed the motor on a definite speed so that it was unnecessary henceforth to press on the gas. About ten minutes later the thirty to forty women were dead."[26]

Two T4 veterans—Scharführer Lorenz Hackenholt who had operated the diesel at the Belzec gas chambers, and SS-Unterscharführer Erwin Lambert (a master mason with long experience in the building trades)—constructed the large "shower rooms" at Treblinka using Jewish slave laborers and Ukranian guards.[27] Treblinka's new building contained 10 gas chambers, which together could hold 1,000 persons at a time. The ceilings had been lowered to a height of 2 meters high to reduce the amount of gas needed and shorten the asphyxiation time, indicating the degree to which the Nazis went to achieve their absolute killing efficiency.[28] Wirth wasted no time in putting the new facilities to work. According to one testimony, by Treblinka's former commandant, Franz Stangl, Wirth "suddenly appeared, looked around on the gas chambers on which they were still working, and said: 'Right, we'll try it out right now with those

25 working Jews. Get them up here.' They marched our 25 Jews up there and pushed them in and gassed them . . . Wirth behaved like a lunatic, hitting at his own staff with his whip to drive them on."[29]

Gassings at Majdanek also started in 1942. Over the entrance to its gas chambers hung a sign that said, "BATH AND DISINFECTION." As one of the smaller killing centers, it had at least three concrete rooms, two of which could hold up to 150 persons each, and a third larger room that could handle up to 300 at a time.[30]

KL Auschwitz-Birkenau in Oświęcimiu, Poland, started out in April 1940 as just another concentration camp, planned as a "transit camp" for Poles. But it ultimately became the largest and most infamous extermination center in history. SS-Obersturmbannführer Rudolf Höss (sometimes written as Hoess) served as its commandant until late summer 1944. In September 1941 one of Höss' deputies (Camp Leader Karl Fritzsch) tested out a new method that would utilize crystallized Prussic acid, mass-produced under the trade name Zyklon-B, which the Army already had been using as a pesticide. The Hamburg firm of Tesch and Stabenow already was supplying it to Auschwitz for the fumigation of barracks and disinfection of prisoners' clothes.When the tin cans were opened to expose the crystals to the air, the chemical reaction released a lethal HCN gas.[31]

The first experiment was carried out when Höss was out of town. As the test site, Fritzsch chose Block 11, the camp's self-contained, solid brick punishment block. On September 3, 1941, 600 famished Soviet POWs and 250 or so ill Polish resisters were ordered to take off their clothes and were crammed into the building's dark basement cells. Then the doors and windows to the cellar were shut and the window wells were sealed with sand. The Germans could hear the sound of conversation for a while. The commander watched as an SS man opened up a canister with a chisel and a hammer, and threw Zyklon-B crystals down into the cellar through a special opening before it too was shut. "Then," the witness later testified, "when the gas was dropped in, there were screams and a rush toward the doors. But both resisted the pressure." The medical orderly immediately closed the hole.[32]

A few Polish political prisoners who were in a nearby attic observed part of the procedure going on and heard a great scream.[33] One of them, August Kowalczyk, later told of seeing "SS men running around with gas masks." Afterwards the Nazis discovered some of the prisoners were still alive. So they strengthened the dose, pouring in more cyanide crystals and sealing the window wells with sand to prevent leakage. The next day, they went back inside and found everyone dead.[34]

Höss later wrote that the experiment with Zyklon-B, rather than hurting his conscience, had eased his troubled mind. "I was always horrified of executions by firing squads," he said. "Now I was relieved to think that we would be spared all these bloodbaths."[35] He liked Zyklon-B because it meant his killers would not have to suffer so much.

After the Building 11 trial run, the Germans continued their efforts to find the more effective and efficient dosage. But the process was not neat. At another gassing that autumn, Hans Stark, the registrar of new arrivals, was conscripted to don a gas mask and pour Zyklon-B into the chute because only one SS "disinfector" had showed up for duty and all of the crystals needed to be poured through both rooftop openings at the same time. A few feet beneath, 200–250 terrified and naked Jewish men, women and children were herded into the fake shower. Stark recalled that the Zyklon crystals "trickled down over the people as it was being poured in. They then started to cry out terribly for they now knew what was happening to them. . . . After a few minutes there was silence. After some time had passed, it may have been ten to fifteen minutes, the gas chamber was opened. The dead lay higgledy-piggledy all over the place. It was a dreadful sight."[36]

The killing was expanded when the Germans built a huge new camp a mile from Auschwitz, at Birkenau. It was designated Auschwitz II and also known as Auschwitz-Birkenau. The Germans had constructed two large bunkers there. Bunker 1 had two gas chambers, and Bunker 2 had four. The camp was designed to allow an entire train to enter its interior. Everyone would be herded from the freight cars and run through a classification process. Their hair was cut and their clothes were taken away. Then they were herded into the chambers for their "*Desinfektion*." It all happened very fast. In 1943 four new installations were put into operation as crematoria. Together they could cremate 4,756 human corpses per day.[37]

At its peak, said Höss, Auschwitz-Birkenau had the capability to exterminate 10,000 people every 24 hours. One of its cavernous gas chambers could kill as many as 2,000 persons at a time. The former commandant later testified, "We were required to carry out these exterminations in secrecy, but of course the foul and nauseating stench from the continuous burning of bodies permeated the entire area, and all of the people living in the surrounding communities knew that exterminations were going on at Auschwitz."[38]

On Saturday, October 7, 1944, Auschwitz prisoners staged a fierce revolt, attacking the SS guards with pickaxes, rocks and their bare hands. Inmates in Crematorium II also mutinied, shoving one of the guards into the oven. Some of the rebels blew up Crematorium IV and its gas chamber along with themselves and numerous guards. Shortly afterward, when Himmler knew the camp would soon fall into enemy hands, on November 3, 1944, he stopped any further convoys to the place and on November 26, he issued the urgent order to destroy all remaining crematoria. The frantic Nazis rushed to destroy as many documents as possible and dynamited all of the gas chambers before they fled. But there was no concealing what they done. Russian troops overran the camp on January 27, 1945.[39]

The murderousness of the Nazi gas chambers was beyond belief. Most of the more than 1 million Jews who arrived at Auschwitz and its sub-camps were sent directly to the gas chambers, though some were kept for a time as slave laborers. More than 200,000 others also died there, many of them exterminated through labor.[40] Although the full numbers can never be known, it is conservatively estimated that at least 1.1 million persons were gassed with Zyklon-B in Auschwitz-Birkenau. In the other killing centers, the gas chambers of Chelmo claimed 152,000 by carbon monoxide; Belzec took 600,000 lives by carbon monoxide; Sobibór's gas chambers killed 250,000; Treblinka's murdered 900,000 by carbon monoxide; and Majdanek gassed 60,000 by carbon monoxide and Zyklon-B.[41] Add to that the tens of thousands of others gassed at Brandenburg, Harthheim, Grafeneck and the other "euthanasia" institutions, and the final toll ran into the millions.

Demands for accountability and punishment of the Nazis resulted in trials for war crimes and crimes against humanity, some of which directly involved their use of lethal gases against civilians and other defenseless prisoners. Dozens of SS officers and other death camp personnel were killed for what they had done. Some were put on trial. After his capture, Kommandant Höss later testified, "I commanded Auschwitz until 12/1/1943 and estimate that at least 2½ million victims were executed and exterminated there by gassing and burning, and at least another half million succumbed to starvation and disease, making a total dead of about 3 million. This figure represents about 70-80 percent of all persons sent to Auschwitz as prisoners, the remainder having been selected and used for slave labor in the concentration camp industries; included among the executed and burned were approximately 20,000 Russian prisoners of war (previously screened out of prisoner-of-war cages by the Gestapo), who were delivered at Auschwitz in Wehrmacht transports operated by regular Wehrmacht officers and men. The remainder of the total number of victims included about 100,000 German Jews, and great numbers of citizens, mostly Jewish, from Holland, France, Belgium, Poland, Hungary, Czechoslovakia, Greece, or other countries. We executed about 400,000 Hungarian Jews alone at Auschwitz in the summer of 1944."[42]

Following his conviction, Höss was hanged at a specially constructed gallows located just a few yards from the former site of the Auschwitz gas chamber.

One major war crimes trial was directed against executives of IG Farben, the immensely powerful chemical and pharmaceutical cartel, from which the German Army received 100 percent of its lubricating oil, more than 80 percent of its explosives and 95 percent of its poison gas. The U.S. lead prosecutor in the Nuremberg War Criminal Tribunal said, "[T]hese IG Farben criminals, not the lunatic Nazi fanatics, are the main war criminals. If the guilt of these criminals is not brought to daylight and if they are not punished, they will represent a much greater threat to the future peace of the world than Hitler if he were still alive."[43] Twenty-four Farben board members and executives of Hoechst, Bayer and BASF were convicted of mass murder, slavery and other crimes against humanity. Among their listed crimes, they had profited from the sale of Zyklon-B and carbon monoxide gas for the gas chambers and utilized slave labor in the concentration camps to manufacture many of their products. Farben employees had also worked with the military to invent and manufacture Zyklon-B and nerve gases and to carry out hideous medical experiments on human subjects. But most of the Farben executives ended up serving relatively lenient sentences.[44]

As the culmination of decades of refinement of the lethal chamber, the Holocaust comprised the greatest single human death toll from man-made lethal gases.

Chapter 9

Nerve Agents

TABUN (ETHYL DIMETHYLPHOSPHORAMIDOCYANIDATE, GA) HITLER'S *WUNDERWAFFE*

Unknown to all but a select few Germans at the time, a new chapter in the history of lethal gases had begun on December 23, 1936, at the IG Farbenindustrie laboratory in Leverkusen, south of Cologne. It was there that Dr. Gerhard Schrader completed a painstaking process of synthesizing various chemicals in hopes of creating a super-deadly new synthetic form of insecticide that would control wooly aphis, a form of aphid. Schrader, who was 34 years old and the father of two young daughters, may have let some of his thoughts wander to the approaching Christmas holiday, which he was longing to celebrate with his family. However, he had to be extremely careful because the ingredients and compounds he was working with were all highly toxic: the fluorides, the phosphates, and especially the cyanide. He had already learned this the hard way. Just a few weeks earlier, after performing the initial synthesis that had exposed him to a very tiny amount of the new mixture, he had experienced some significant reactions. His vision blurred, his head throbbed, and he suddenly became painfully short of breath. And that was just the beginning. Over the following hours, his symptoms had worsened, forcing him to take to bed, and he had spent two weeks in hospital and another week recuperating in bed. Some side effects still lingered.

But now Schrader was back in the lab, finalizing the distillation to retrieve a handsome new product. In his hand the glass container yielded a clear, colorless liquid bearing a faint scent of apples, which he labeled Preparation 9/91. When heated, the substance assumed a gaseous form. It looked good. After admiring his creation, he gave a small sample of it to his assistant, Karl Küpper, who tried 5 parts per million of it on leaf lice and determined that it was 100 times more effective than the original substance—astonishingly potent, they noted. Schrader and Küpper believed they had been extremely cautious, but within hours of coming in contact with only minute amounts of the preparation, both researchers were overcome with the same symptoms Schrader had experienced weeks before. It took them weeks to recover, and both ended the ordeal feeling lucky to survive.

By now, Schrader had gleaned that his new creation would kill more than bugs. The gas he had discovered was ten times more lethal than Germany's deadliest war gas, phosgene. The name selected for this ethyl-dimethyl-amido-phosphoro-cyanidate was "taboon" (later changed to "tabun"). Unlike other insecticides or war gases, tabun attacked the central nervous system, inhibiting the function of a specific chemical in the body known as cholinesterase, and thereby creating a situation where the victim's bodily functions were no longer under the brain's control. Tabun was the first poison gas to work by shutting down the transmission of nerve impulses. Hence it was a nerve agent.[1]

Schrader's discovery built on the path-breaking research done by another German-Austrian scientist. In 1921 Otto Loewi had been the first to prove the idea of chemical transmission of nerve impulses. As Loewi himself later explained it, he had been able to obtain "certain proof that by stimulation of the nerves in a frog's heart, substances were released which to some extent passed into the heart fluid and, when transferred with this into a test heart, caused it to react in exactly the same way as the stimulation of the corresponding nerves. In this way it was proved that the nerves do not act directly upon the heart, but rather that the direct result of nerve stimulation is the release of chemical substances, and that it is these which bring directly about characteristic changes of function in the heart."[2]

After establishing the role chemicals play in the transmission of nerve impulses, Loewi had spent several years trying to unlock the mystery of what those chemicals were. The first neurotransmitter he identified was acetylcholine (or what he originally called "vagus substance"). Acetylcholine turned out to have many functions for the human body. It is responsible for stimulating the muscles, notably those of the gastrointestinal system. It is also found in sensory neurons and assists the autonomic nervous system.

Loewi's discovery of neurotransmitters opened up a new realm in understanding the human body, and others were racing to come to terms with its implications. Just eleven days before Schrader became the first to synthesize his nerve agent tabun, Loewi had given a lecture in Stockholm accepting his Nobel Prize in physiology or medicine. But Loewi was Jewish. In his own homeland he was suffering disdain, even persecution. Ironically, within a few months, the Nazis would seize Loewi's prize money and force him to leave the country.[3]

After the Christmas holidays, scientists at IG Elberfeld conducted further tests of Schrader's early tabun sample, administering some of the vapors to apes in a gas chamber, with suddenly fatal effect—so much so that the testers concluded that the substance was far too lethal to warm-blooded animals to be commercially marketed as an insecticide. That did not disappoint IG Farben, however. The Nazi regime had a growing fondness for highly toxic chemicals. In 1935, Benito Mussolini had employed chemical weapons with impressive results in Abyssinia, and the Nazis required that all new inventions having possible military significance had to be reported to the Ministry of War, which would classify any ones it wished if they were deemed useful for the defense of the Fatherland.

The paperwork and sample from IG Elberfeld soon ended up in the Army Weapons Office at Spandau, the medieval fortress housing Germany's chemical warfare section, where it prompted a flurry of memoranda, tests, and demonstrations on laboratory mice. Everything proved so impressive that Schrader was summoned to Berlin to demonstrate the synthesis of his deadly mix, which now was rated as Germany's most potent poison. Schrader's patent application was kept top secret and he was transferred to a new laboratory at Wuppertal-Elberfeld in the Ruhr valley, where he and his supervisor were awarded 50,000 marks for their discovery.

The Army constructed new secret laboratories to further investigate tabun and other related compounds, establishing a pilot-scale production complex at Munster-Lager near the Army Proving Ground at Raubkammer to make the gas. Researchers put the gas through a battery of tests in the open air and the gas chamber, so scores of scientists in lab coats and high-ranking officers could observe its effect on guinea pigs, cats, dogs, monkeys, horses and apes. Tabun-filled artillery shells and aerial bombs howled through the air onto an elaborately marked target zone as teams of meteorologists, gunnery experts and chemists at carefully placed vantage points monitored the results with instruments. The military men liked its extraordinary toxicity, its ability to evade detection until it was too late, and its long-lasting hazardous effects, but they noted that it was best suited for tropical climates or summer campaigns rather than the brutal Russian winter. The whole operation moved with electric efficiency. But it also produced hundreds of serious injuries.[4]

In 1938 Field Marshal Hermann Göring, commandant of the Luftwaffe, ordered a detailed plan for Germany's chemical rearmament, and the task fell to IG Farben's top dog. Karl Krauch, the supervisory head of IG Farben's board of directors, lauded poison gas as "the weapon of superior intelligence and superior scientific-technical thinking," which he said Germany should employ "in a decisive manner, both on the front and against the enemy's hinterland."[5] (Krauch would later be sentenced at Nuremberg for war crimes.)

The Germans quickly refined the tabun development process well enough to yield a substantial quantity of the poison—just in time before the war began. Tabun, then known by its code name of T-83 or Trilon 83, was expected to be one of Germany's aces in the hole—a *wunderwaffe* or wonder weapon.

In January 1940, the Nazis began constructing a major plant to manufacture tabun. Code-named *Hochwerk*, it was located in the forest at Dyhernfurth-am-Oder, on the Oder River, and run by IG Farben under government contract. Most of the plant was underground and camouflaged by trees on its roof. After taking more than two years to become operational, it began synthesizing the precursors as well as the final product. Some chemicals were so corrosive that the Germans took to using quartz- or silver-lined vessels. The tabun production units were "enclosed in double glass-lined chambers with pressurized air circulating between," and featured an apparatus that had to be constantly decontaminated with steam and ammonia. Nevertheless, at least 10 workers perished due to accidental exposures, and hundreds more were badly injured. The Germans also used slave laborers at the plant. By the end of the war it had turned out 12,869 tons of tabun.[6]

Polish secret agents and other sources warned the Allies about the Germans' chemical warfare activities almost as soon as they happened, but many warnings were dismissed as propaganda or disinformation. In July 1943, British intelligence interviewed a captured German chemist who had worked in the chemical warfare branch at Spandau; he provided a detailed description of a fearsome new agent, code-named Trilon 83, outlining its effects, method of use and defense, and reporting on the status of its production. But the MI9 intelligence report about tabun was largely ignored.[7]

As the fortunes of war shifted against Germany, the Nazis loaded their tabun into projectiles and aircraft bombs, which they hid at various sites in Upper Silesia and in mine shafts in Lausitz and Saxony. Some tabun stocks were later moved to Bavaria in anticipation of a final assault. Himmler urged Hitler to use gas against their enemies, but Hitler still resisted.

In August 1944, the Red Army was approaching Silesia, and the Allies had begun their race for the German border. The Nazis frantically began to eliminate any evidence regarding their poison gas activities, always trying to stay one step ahead of the advancing invaders. They burned records, dynamited laboratories, and removed or destroyed chemical stockpiles. In early 1945, they abandoned Dyhernfurth, hastily dumping tons of deadly liquid nerve agents into the Oder River. But the Russians arrived before the plant could be detonated, and the Luftwaffe also subsequently failed to destroy it. As a result, Soviet troops seized the plant and much of its contents virtually intact. Stalin later ordered everything dismantled and transported to Russia. Agents also tracked down many of the Germans' secret laboratory notebooks and other documents telling them a great deal about the enemy's new nerve gases.[8]

A few months later, British troops also stumbled upon 105 mm howitzer shells filled with a strange liquid and marked with a green ring and the letters GA. An arsenal of 71,000 250 kg aerial bombs filled with tabun were brought to Britain and stockpiled for possible use in the invasion of Japan—but the gas was never used.[9] Within a few years, the shells began to leak, and in 1955–56, the British carried out Operation Sandcastle in which they loaded Hitler's tabun weapons onto ships and sunk them off the Irish coast.[10]

SARIN (ISOPROPYL METHYLPHOSPHONOFLUORIDATE, GB, GB2)

After Schrader made his breakthrough with tabun, he had continued work on developing other new toxic war substances. At Wuppertal-Elberfeld in 1938 he discovered a new compound, isopropyl methylphosphonofluoridate, with "astonishingly high" lethal potential. The Nazis called it "sarin." Its name was an acronym taken from letters in the names of its four chief creators: Gerhard *S*chrader and Otto *A*mbos of IG Farben, and Colonel *R*üdiger and Van der L*in*de of the Army.[11] German scientists prepared their first samples of sarin just a few days after the Wehrmacht's invasion of Poland. Extensive secret experiments on animals and humans determined that the stuff was deadlier than tabun and up to 500 times more lethal than hydrogen cyanide.[12]

The few Nazis who knew about it were secretly thrilled. On September 19, 1939, Hitler gave a rousing address at Danzig, boasting that Germany possessed fearsome new weapons against which its enemies were defenseless. Although he did not specify any by name, his warning did not ring hollow, for the Army already had added tabun and sarin to its arsenal, for which the Allies were woefully unprepared.[13] The Nazis thought they were invincible.

SOMAN (PINACOLYL METHYLPHOSPHONOFLUORIDATE, GD)

In the late fall of 1944, Carl Baumann was a 38-year-old biochemistry professor at the University of Wisconsin when the U.S. War Department summoned him on a secret mission. Before the war, Baumann had served a fellowship under Richard Kuhn at the Kaiser Wilhelm Institute for Medical Research in Heidelberg. In 1938 Kuhn had received the Nobel Prize in Chemistry for his studies on carotenoids and vitamins. Baumann, being fluent in German and quite knowledgeable about German chemical research methods, was assigned to look into an important matter. To his surprise, he was outfitted for a crucial foray behind enemy lines. His mission was part of Operation ALSOS, a top-secret intelligence effort aimed at capturing, detaining, and interrogating important German scientists, as well as locating any uranium that might be held by the Nazis.[14]

Baumann did not know it yet, but American agents were trying to protect their own secret weapon, the atom bomb; they also were desperate to keep the Nazis from beating them to the punch with their own nuclear weapons. On his first probe into war-torn Germany, Baumann participated in the interrogation of his former supervisor and friend, Dr. Kuhn. Later Baumann came upon a trove of classified chemistry documents about some of Kuhn's secret military research, which he used to interrogate Kuhn again. He teamed with another former Kuhn assistant, Professor Louis F. Fieser of Harvard University, who had since joined the U.S. Army, to learn about the German chemist's work on a deadly new nerve gas, "soman."[15]

A year or so earlier, in 1944, in the wake of Schrader's synthesis of tabun and sarin nerve agents, Kuhn and his collaborator, Konrad Henkel, had been screening a variety of organophosphate compounds for the ability to inhibit cholinesterase, when Kuhn made another important discovery. Upon replacing some of the isopropyl alcohol used to make sarin with a more complex alcohol known as punacolyl, his synthesis created a new substance (which he called Compound 25075) that had a pungent odor like camphor. Their initial tests found it to be twice as potent as sarin in inhibiting cholinesterase. A sample of it, along with the paperwork, was sent to Elberhard Gross at IG Elberfeld, who put the substance through a series of tests. Gross tested it on dogs and apes with staggering success. The results were very promising. The compound was found to be twice as strong as sarin through inhalation, and it readily penetrated the skin and passed rapidly from bloodstream to brain, thereby enhancing its lethal effects. It also deactivated cholinesterase irreversibly within just two minutes–much faster than sarin—thereby severely limiting the effectiveness of any antidote. The War Department was pleased: they named it soman.[16]

The Nazis tried out their new gases on prisoners in France. In one series of tests involving various possible antidotes, Dr. Karl Wimmer, a Luftwaffe doctor, and Professor August Hirt, a Nazi anatomist from nearby Strasbourg University, experimented with various antidotes using inmates of the Natzweiler-Struthof concentration camp.[17] After the camp was liberated on November 23, 1944, a *New York Times* correspondent reported, "It might have been a Civilian Conservation Corps camp, from the winding road to the bald hilltop, the sturdy green barrack buildings looked exactly like those that housed forestry trainees in the United States during the early New Deal." Survivors pointed to a gas chamber. The GIs also came across a grisly dissection room, a crematorium, and piles of human hair.[18] American intelligence pulled together everything about the Germans' chemical warfare activities and sent it back to their chemical warfare center at Edgewood.

The Americans were not the only ones who were hot on the trail of Germany's chemical weapons legacy. Shortly after World War II ended, a Russian chemist who was accompanying Soviet forces occupying vanquished Germany, uncovered a cache of secret documents buried in a mine shaft at Rüdersdorf outside Berlin. The records were identified as laboratory notebooks and other crucial information describing the synthesis of soman. With it the Soviets gained the recipe for a valuable weapon of mass destruction for their arsenal, and Stalin's generals wasted no time in using it to begin cooking up large supplies of the compound for possible use in the next world war.[19]

Over the next few years, as the Cold War intensified and U.S. military commanders became more aware of Soviet chemical warfare capabilities, American researchers devoted particular attention to nerve agents, developing several more varieties of sarin. After conducting an extensive study that compared all of the nerve gases, one of the chemical engineers, Benjamin K. Harris, argued to his supervisor that soman was superior on several counts. But because its production required pinacolyl alcohol, which was costly and difficult to produce, Army higher-ups ended up instead favoring sarin over soman.[20]

During the early 1950s, the United States. and the United Kingdom collaborated to secretly test chemical and biological weapons. Some of the soman tests were carried out at Britain's Porton Down in Wiltshire, England. A young Royal Air Force recruit, Lawrence McAndrew, who had volunteered to help find a cure for the common cold, ended up as one of 3,100 British servicemen to be intentionally exposed to nerve agents. In 1951, as part of one experiment, McAndrew was injected with liquid nerve gas, and he went temporarily blind. Nearly 50 years later, in 2000, a newspaper investigation turned up piles of declassified government documents detailing the Allied human experimentation program. The officials who oversaw the experiments charted in detail the blindness, chest pains, nausea, headaches, nightmares and collapses that affected the servicemen. "Severe headache and pain behind the eyes, which gradually increased in severity. There was disorientation, great difficulty in breathing and severe vomiting," wrote one observer of a 19-year-old exposed to the nerve gas soman in 1951. Another experiment in the same year involved dripping liquid soman and two other nerve gases, sarin and GF, onto 396 men, "to determine the dosage which, when applied to clothed or bare skin of men, would cause incapacitation or death," according to an official report. Five of the servicemen had to be hospitalized and one (20-year-old airman Ronald Maddison) died from heart failure as a result of their exposures. The British nerve gas experiments were a clear breach of the Nuremberg code because the volunteers had not given their informed consent. The revelations unleashed a firestorm of lawsuits and criticism in the United Kingdom.[21]

VX ($C_{11}H_{26}NO_2PS$)
DUGWAY

Skull Valley, Utah was a former Indian battleground that took its name after some of the early white settlers discovered hundreds of human skulls littering the endless barren salt flats. Orrin Porter Rockwell, a legendary Utah lawman and religious zealot (and one-time bodyguard of Joseph Smith and Brigham Young), known as "The Destroying Angel," owned a ranch at the southern end of Skull Valley, where he cultivated a reputation as a man who could not be killed. In the late nineteenth century, the Mormons chose Skull Valley as a new "gathering place" for Hawaiian converts who had migrated to Salt Lake City to participate more closely in the Mormon Church. They called it "Iosepa." But after their flock's numbers were decimated by leprosy, diphtheria, and smallpox, the survivors were relocated back to Hawaii, leaving it a ghost town, populated by lizards and snakes and overrun with sagebrush. The valley remained the province of the secretive Goshute Indians, whose reservation and a few scattered ranches were surrounded by huge federal tracts designated as military testing sites.[22]

On March 14, 1968, a bizarre event occurred in Skull Valley that turned out to be a milestone in twentieth-century history. It was on that date that a range supervisor, Alvin Hatch, made a shocking discovery: he reported that 3,000 sheep belonging to the Anschutz Feed & Livestock Co. of Denver had suddenly and mysteriously died, while thousands more lay twitching on the desert floor. The incident amounted to a sizeable loss for the owners, in part because the sheep were not insured.

When nobody could figure out the cause, suspicion soon focused on some of the hush-hush activities emanating from the Army's super-secret Dugway Proving Ground, 27 miles to the west. In 1941, when the Chemical Warfare Service had determined it needed a testing facility more remote than Edgewood Arsenal in Maryland, it chose the Utah site as its favorite target range and dumping ground, keeping what went on there a tightly guarded secret. At the time of the great sheep kill in 1968, the Vietnam war was raging in Southeast Asia and the Viet Cong had just mounted their Tet Offensive, making many savvy observers around Salt Lake wonder what horrible new secret weapon might be getting tried out in the desert.

Blood tests on the sheep revealed that some sort of organophosphate chemical had poisoned them, and investigators figured out that the deaths had occurred just one day after the military conducted open-air tests at Dugway. The U.S. Army denied responsibility and initially suggested some organophosphate pesticide as a possible source; however, veterinary autopsies later identified the presence of the lethal organophosphate nerve agent VX—whispered to be one of the world's deadliest chemical weapons. The local Indians were concerned that the contaminated carcasses of the dead sheep had been buried on their ancestral land. News of the discovery flashed around the world, igniting a global storm of antiwar and environmentalist criticism. Although the U.S. military continued to deny responsibility, President Richard M. Nixon responded several months later by banning all open-air chemical weapon testing.

The Dugway sheep kill went down as another long-contested military obfuscation, until 1998, when a reporter for the *Salt Lake Tribune* discovered a hidden Army report indicating the military had killed the sheep when an aircraft spray nozzle malfunctioned during open-air tests, causing the F4 Phantom jet to accidentally discharge 20 pounds of VX nerve agent into the air. Winds gusting to up to 35 miles per hour carried some of it down into the valley 20 miles north of the target area. After the Dugway incident, any effort to make, move, dump or use VX encountered stiff public opposition.[23]

The emergence of VX and other second-generation nerve agents had grown out of the Nazis' work on organophosphate compounds for military use in World War II. After the war, American, British and Russian chemists rushed to pick up on the Germans' discoveries, hunting down every Farben chemist and scrap of paper they could find, scurrying to determine the potency of every new substance. They also scrambled to devise their own new nerve-agent chemical weapons. In 1952, Dr. Ranajit Ghosh, a research chemist for the British firm Imperial Chemical Industries (ICI), was investigating a new class of organophosphates as a possible pesticide.* Ghosh and his colleague J. F. Newman synthesized a compound containing nitrogen and sulfur. They discovered the new substance was extremely effective for killing lice—and they concluded it could also be highly lethal to humans. The researchers sent a sample along with paperwork to Britain's chemical warfare center, Porton Down. Porton's CW laboratory quickly tested the compounds and alerted their American counterparts at Edgewood, who also commenced a systematic investigation. In 1954, ICI began to sell the new organophosphate under the trade name Amiton, but soon the company had to pull it from the market for being too unsafe to humans.[24]

Researchers began to refer to the new class of compounds as the V class of nerve agents. Amiton was labeled VG; another type developed at Edgewood was named VX. Laboratory tests showed the V-series nerve agents to be far more toxic and durable than mustard gas.[25] Liquid VX is heavier and more viscous than previous nerve agents, with a texture and feel like high-grade motor oil. Under average weather conditions, VX can persist for days, and in cold temperatures it can last for months. It also has little or no smell and can be distributed as a liquid or vapor. Depending on the method of absorption, as little as 200 micrograms of VX was all that was needed to kill a human being, making it the most deadly poison discovered to that point.[26]

The discovery of VX came at a propitious time for the U.S. military. Studies had determined that its stocks of World War II-era chemical weapons munitions were no longer suitable for use, yet the Army and Air Force were disagreeing over what agents to choose for future manufacture. Following extensive tests on soldiers at Edgewood Arsenal, in 1958 the United States selected VX, based in part on its particular effectiveness in cold climates such as Russia or Korea.

Construction of the VX production plant in Newport, Indiana began in 1959 and was completed in 1961 at a cost of $16.5 million. The facility produced more than 5,000 tons of VX from 1961 through 1968. Much of the VX was used to arm land mines, artillery shells, and rockets. After President Nixon halted production of chemical weapons in 1969, the manufacturing plant was decontaminated as much as possible without disassembly, then fenced off and left to rust.

The Soviets, meanwhile, had developed their own V-series nerve agents. By the 1980s other nations including the United Kingdom, France, Syria, and Iraq were also known to possess some version of active V-series nerve agents.

VX blocks the function of a crucial enzyme for nerve response and function. By preventing the action of acetylcholinesterase, VX produces contractions of

*Founded in 1926 by the merger of four British chemical companies (Nobel Explosives, British Dyestuffs Corp., United Alkali Co., and Brunner Mond), ICI emerged as the competitor to Germany's IG Farben and America's DuPont.

muscles throughout the human body. Sustained contractions can cause death by asphyxiation. One of the characteristics that make VX an effective weapon is that it is odorless, so a person who has been exposed to it may not know it. Within seconds to hours of exposure, however, someone who has inhaled, ingested or absorbed a low to moderate amount may experience a tidal wave of worsening symptoms. Skin exposure to even a microscopic drop can set off intense sweating and muscle twitching; a larger drop on the skin may cause the person to die. Death can sometimes be averted, but only if the victim gets the appropriate antidote immediately after exposure. The only known antidote is atropine, pralidoxime (2-PAM) and diazepam, commonly administered by autoinjector.[27] Some military forces have made their soldiers practice the autoinjections. But VX is an extremely deadly substance.

The only suspected use of VX in war occurred in the Iran-Iraq war of the 1980s, when Iraq appears to have used it against Iranian troops and civilians as well as Kurdish civilians in Iraq. The United Nations subsequently classified VX as a weapon of mass destruction; its production and stockpiling was outlawed by the Chemical Weapons Convention.

The United States stopped producing VX in the late 1960s. Earlier in the Cold War, the Army simply dumped some of its stockpile into the ocean. But that practice was halted, and for nearly 40 years most of America's remaining VX stockpile was kept at the Newport Chemical Depot in central Indiana. When the Army moved to dispose of its existing VX stockpiles, the decision was made to treat, destroy, and dispose of the nerve agent in Newport. But the Army later opted to treat the nerve agent on site, converting it into VX hydrolysate, and then transporting the material to a different facility for final treatment and disposal. On June 12, 2005, more than 250,000 gallons were stored at Newport. A stockpile of 1,269 tons was slated for appropriate disposal or destruction. But the question remained: how would that be done? At first, the Army proposed to dump the hydrolysate into the Great Miami River, near Dayton, Ohio, but the community there successfully defeated the proposal. Later, a plan was developed to truck the hydrolysate from Indiana to the DuPont Chambers Works Secure Environmental Facility at Deepwater, New Jersey, where it was supposed to be further treated and then dumped into the Delaware River. But that plan also proved extremely controversial, and the governors of Delaware, New Jersey, Pennsylvania, and New York all opposed it. New Jersey's governor instructed his department of transportation to block any truck from carrying VX hydrolysate into the state.[28] Finally, after a lengthy struggle, in June 2007, DuPont announced it was no longer seeking a contract from the U.S. Army to dispose of the VX nerve gas hydrolysate stored in Newport, marking a major victory for environmentalists.[29]

But the question remains: where on earth will the VX go?

Chapter 10

Carbon Monoxide (CO): The Silent Killer

One day in 1846 a young French physiologist, Claude Bernard, was in his laboratory studying the properties of a gas that appeared to form from the combustion of carbon-containing compounds. Although tasteless, odorless and invisible, it was known to be extremely deadly and to cause more accidental deaths than any other gas. Bernard realized it could prove lethal, but he knew nothing about the *mechanism* of its poisoning.

Therefore, he set out to explore this mysterious lethality by means of scientific experiment. His idea was to poison a dog by forcing it to breathe the gas, dissect it, and examine the result. Bernard already had killed hundreds of dogs, cats, and other animals in his experiments, starting in his apartment kitchen in the Old Latin Quarter in Paris and continuing on to this well-equipped scientific laboratory, so he knew how to take some precautions. Once he had killed the creature by pumping the gas into its body, he immediately took a scalpel, opened up the carcass, and began studying the exposed organs and fluids. First he was interested to see that all of the blood was crimson.

Each time he repeated his experiment, regardless of whether it involved rabbits, birds, or frogs, he found the same crimson color. A decade later he conducted even more experiments with the gas in his laboratory-turned-killing chamber; each time he carefully recorded every step and noted every result. One time Bernard passed a stream of hydrogen through the crimson venous blood taken from an animal poisoned by carbon monoxide, but for some reason he could not displace the oxygen. An attempt using arterial blood met the same result.

Then Bernard set out to study monoxide's action on the blood by *artificial poisoning*. To accomplish this he obtained some arterial blood from a healthy animal and placed it under mercury in a test tube containing carbon monoxide; then he agitated the entire setup in order to "poison the blood while protecting it from contact with the outside air." Afterward he checked to see if the air in the test tube had changed. The results were significant, for the air in contact with the blood was "notably enriched with oxygen," while the "proportion of carbon monoxide was diminished." It led him to conclude that the poisonous gas carbon monoxide displaced vital oxygen in the blood.[1]

Not long after these experiments, Bernard's own health suddenly deteriorated, most likely as a consequence of his gas experiments. He died at age 64. Today he is known as the "father of experimental medicine." Bernard's analysis of the physiological action of carbon monoxide had far-reaching repercussions, for it showed that the gas rapidly poisoned animals "because it instantly displaces the oxygen of the red corpuscles and cannot itself be subsequently displaced by oxygen." It also demonstrated the beneficial effects of blood transfusion in carbon monoxide poisoning and helped to establish the fundamental method of determining blood oxygen content.[2]

At 6:40 A.M. on January 2, 2006, residents around the ramshackle Appalachian hamlet of Tallmansville, West Virginia, felt the ground shake and heard a rumble like thunder coming from deep in the earth. Dishes rattled. Minutes later, sirens screamed and telephones started ringing. The news was shocking: a gas explosion had trapped 13 men somewhere deep inside the Sago Mine, more than two miles from the mine's only entrance and down about 260 feet from the surface.

The cause of the blast was unknown. However, a coal mine explosion typically results from the ignition of built-up naturally occurring methane gas, which often becomes more volatile in the cooler, drier winter months. Miners use wells to extract methane from coal seams and sealed areas inside the mines, and this methane can prove dangerous. After the Sago collapse, some observers speculated that lower atmospheric pressure accompanying a recent storm system might have caused a quantity of hazardous methane to escape. Sensors indicated there had been at least two lightning bolts striking the ground near the mine around the time of the explosion. and one of them had been unusually powerful. Thus a company spokesman theorized that the lightning may have struck a leaking methane well and ignited the gas, causing an explosion that triggered the roof fall deep down below the surface.[3] Whatever its cause, the blast had created a terrible situation. Besides causing a cave-in, the explosion had also generated a large quantity of lethal carbon monoxide and other deadly gases.

Every Sago miner was supposed to carry his own "rescuer"—a self-contained oxygen device that supplies up to one hour of breathable air. Additional emergency supplies had been stored in 55-gallon drums stationed at intervals throughout the mine, but there was no way to know if the trapped miners were able to reach them. Without assistance, the men were in very deep trouble.

Their relatives and friends were desperate to reach them, but numerous hazards hampered the rescue efforts. The searchers' air quality detectors showed dangerous levels of carbon monoxide, and they also feared another possible explosion. Attempts to deploy a one-and-a-half-ton robot failed when it became mired inside. It took rescuers 24 hours to clear a road, pinpoint the victims' likely location, and drill a hole for the device that gave them their first glimpse into the suspected area. In order to pass information from the depths of the mine to the outside world, workers with the rescue team, fresh-air base, and command center had to rig together a cumbersome communication system involving handheld radios and a crude phone line, which did not work very well. One action after another yielded poor results. Readings taken from an area near where the miners were last known to have been stationed showed a volume of carbon monoxide more than three times the maximum breatheable level. Then more bad news arrived when a video camera they had sent down did not pick up any images of survivors or signs of barricades the men would have built to try to ward off the poison gas.

Known as the "silent killer," carbon monoxide is an odorless, colorless, tasteless gas that can cause sudden illness or death. The product of incomplete combustion, it is typically found in exhaust fumes, such as those produced by cars and trucks, small gasoline engines, improperly vented stoves and furnaces, and burning charcoal, wood, or gas such as burning methane. Carbon monoxide gas can accumulate inside enclosed or semi-enclosed spaces, poisoning anyone who breathes it.[4]

Aboveground, the Sago scene was packed with network TV satellite trucks, emergency vehicles, business trailers, and cars. Dozens of tripods with cameras and lighting equipment ringed the area. The flock of reporters and government officials fluttered about like vultures.[5]

Down below it was another world. Members of the news media began to report that Sago Mine had been cited for scores of safety violations for seepage of volatile gas and roof collapses. Yet federal regulators had not penalized the company for its poor record. In the preceding three months alone, Mine Safety and Health Administration (MSHA) inspections had brought 46 citations and 3 orders, 18 of which were "serious and substantial." Yet the owner and operator, International Coal, denied that any of the conditions were life threatening, while federal officials were left to battle accusations that they had failed to properly regulate the operation.[6]

In the end, after various false reports had circulated, it was announced that all but one of the trapped men had been found dead. The lone survivor was the youngest miner, Randal L. McCloy, Jr.

More details began to emerge about what had happened. Three weeks before the explosion, McCloy and fellow miner Junior Toler were working at the end of their shift when McCloy discovered a gas pocket. As soon as their gas detector confirmed the presence of methane, the men immediately took the necessary precautions and reported the incident up the line to their superiors. The next day McCloy noticed that somebody had plugged the gas leak with glue.

Moments after the explosion on January 2, McCloy and his crew were shocked when the mine suddenly began to fill with fumes and thick smoke, making breathing nearly impossible. And that was only the beginning. Although each miner was equipped with a portable rescuer, at least four of the emergency oxygen packs were not working. McCloy elected to share his device with one of them, while the three others turned to the rest of the team for help. None of their radios worked. And they could not reach the closest stash of emergency supplies. Due to these problems, and the bad air, they had to abandon an escape, leaving everyone to return to the coal crib, where they hurriedly hung a row of plastic curtains in an attempt to protect themselves from the invading gas. The curtains enclosed an area measuring about 35 feet. Some of the men took turns beating on the mine bolts and plates in a frantic attempt to signal their location. One after the other took his turn smashing with a sledgehammer, but the exertion soon made it too hard to move or breathe. They never heard a response. Finally, after becoming exhausted, they gave up trying to signal and concentrated on trying to conserve their air. With the air inside the curtain growing worse, the miners focused all their efforts on trying to lie as low as possible and breathe as little as possible, taking shallow breaths. Methane does not have a detectable odor, but they could tell it was gassy. And there was also carbon monoxide to worry about.

Two men tried to find a way out, but the heavy smoke and fumes forced them to return. There was too much gas. Eventually the miners began to come to terms with their fate. Huddling together on the hard ground, one of them (Junior Toler) led the group in prayer.

Forty-one hours after the explosion, the exhausted rescuers had worked their way 13,225 feet into the mine when one of them discovered the battices (curtains) where the trapped miners had barricaded themselves from the lethal gases. Somebody heard a voice moaning and they pulled back the curtain. The bodies were scattered about. They were all dead, except for one who was barely alive. It was Randy McCloy. He was unconscious but still wearing his breathing apparatus and making strange sounds; they immediately hooked him up to a respirator and carried him as fast as they could, hustling three-quarters of a mile on foot before taking him by tram the remaining two miles to the exit.[7]

McCloy was a 26-year-old husband and father of two small children. Nobody knew how he alone could have survived the ordeal. His wife, Anna, said she believed he had been saved by his love for his family and his faith in God, and she speculated that some of the others, knowing he was the youngest, with a wife and kids to support, might have selflessly contributed to his survival by giving him some of their oxygen.[8]

The medical experts were amazed he was still alive, for nobody exposed to acute carbon monoxide poisoning for anywhere near that long had ever survived before. Some doctors warned that McCloy faced an uphill struggle to survive and even greater challenges to emerge as a normal person. Many victims of severe CO poisoning either die or suffer severe and lasting neurological injury; most survivors can be expected to exhibit some degree of psychiatric symptoms. The treatment prospects for someone with severe CO poisoning were mixed. In the 1950s and 60s, some patients were subjected to hypothermia, but by the 1970s controlled studies showed no benefit for that approach.[9]

Nobody knew what lay ahead for McCloy. After being removed from the site at approximately 1:30 A.M. on January 4, the young miner's limp body was rushed by ambulance to the nearest hospital. There a surgeon found him to be unconscious but moaning, and his condition was classified as "critical." All indications pointed to gas poisoning, but it was unclear precisely what or how much carbon monoxide, methane, or other toxic gas he had ingested. Later that morning the patient was moved 50 miles by ambulance to a level 1 trauma center in Morgantown, where hospital officials found he was suffering from "acute carbon monoxide poisoning, a collapsed lung, brain hemorrhaging, edema, muscle injury, and faulty liver and heart function."[10]

For such a condition the standard treatment was known to be hyperbaric oxygen therapy. A hyperbaric chamber is a large steel room like a diving bell in which air can be compressed to a pressure equivalent to two times normal atmospheric pressure. (The largest such chambers can accommodate up to 15 persons at a time.) These devices have been in use for decades to treat deep-sea divers suffering from decompression sickness, known as "the bends." Often thought of as a treatment for divers and astronauts, hyperbaric oxygen treatments are also the fastest way to reduce the amount of carbon monoxide in a person's blood. The chamber's purpose is to deliver oxygen to the bodily organs that have been deprived of oxygen for prolonged periods of time.[11] Doctors agreed that hyperbaric therapy probably offered McCloy's only hope. But since there was no hyperbaric oxygen tank in the region, they moved him to the nearest one.

On January 5, McCloy was transferred to Pittsburgh's Allegheny General Hospital to receive oxygen infusions that might counterract the effects of carbon monoxide. Still in a coma, he entered the hyperbaric chamber for a series of intensive treatments. Three days later, a hospital official said he was showing signs of improved brain stem and organ function but was "not out of the woods."[12]

The hyperbaric treatment had helped him survive, but his prognosis remained shaky. He would spend the next two months being shuffled from one medical facility to another as doctors struggled to combat the ill effects of his acute carbon monoxide poisoning. In April he appeared in a television interview, saying he remembered bits of the accident, but he was not sure what month or year he was in.[13] The injured miner was incredibly lucky to have lived, because he had been exposed to high doses of carbon monoxide along with other toxic gases and denied oxygen hundreds of feet underground for 41 hours—longer than anyone else on record. It all added up to a devastating blow to his system, but he was able to survive and resume living a relatively normal life.

Prior to McCloy's case, one of the best-known successful recoveries from CO poisoning in America had involved Catherine Mormile, a 51-year-old athlete who was competing in her third Iditarod race in Alaska in 1994 when she stopped to change her wet socks. The tent proved to be unvented. Minutes later, she felt nauseous. Then she fell unconscious. "I tried to stand up, and I had to hold onto the frame of the tent," Mormile later recalled. She had breathed carbon monoxide for three hours. It took her years to recover from the ordeal.

Her IQ had dropped. Besides having to relearn skills such as reading and writing, her biggest hurdle was to recover emotionally.[14]

Other victims were not so lucky. In 1994 the professional tennis star Vitas Gerulaitis died from accidental carbon monoxide poisoning after an improperly vented pool heater allowed CO to build up in a pool house where he was sleeping.[15]

Carbon monoxide intoxication is the most common cause of poisoning death in the United States, annually accounting for 500 or so unintentional deaths and more than 2,000 suicides—the latter typically being victims who poisoned themselves by running a car engine in a closed garage. An estimated 10,000 or so Americans annually seek medical attention due to CO poisoning. Mortality rates currently range from 1 or 2 percent to 31 percent or more. Although its full incidence remains unknown, an estimated one-third of all cases go undiagnosed. Yet the known death rates have been declining in recent decades.[16]

Although the potentially fatal effect of acute carbon monoxide poisoning has been recognized for centuries, its long-term impact on survivors is much less known. Recent studies have suggested it often results in impaired thinking and reasoning.[17]

Peter Johnston has had to live with these consequences. On the Monday after Easter in April 1965, Johnston was living in a converted fire hall in Milwaukee when he was discovered unconscious in his bed. The furnace in the building had malfunctioned, filling the space with carbon monoxide. After finding him unresponsive, doctors placed him in a hyperbaric chamber for an hour and tried some other treatments until he slowly began to regain consciousness. Within a few days he gradually recovered to a point, but continued to exhibit memory and speaking problems. More than 40 years later, Johnston says he suffers from aftereffects of the poisoning, including diminished verbal (and written) communication skills, short-term and long-term memory loss, nausea, poor appetite, headaches, drowsiness, torpidity, ambivalence, bladder control problems, diminished balance control, and an impulsive need to count things and to constantly keep track of the time it takes to do different things like brushing teeth, taking showers, or other tasks, as well as other quirks. Unless carbon monoxide is suspected, such poisoning can prove difficult to diagnose because its symptoms often mimic those of flu or drunkenness. Persons who are exposed to carbon monoxide while sleeping may simply never wake up.[18]

Although everyone is vulnerable to carbon monoxide poisoning, those at highest risk include infants and persons with chronic heart or respiratory problems. Carbon monoxide poisoning often occurs during power outages, when more people resort to indoor generators or grills. In December 2006, more than 100 persons in the Seattle area were hospitalized, and some died or suffered lasting injury as a result of such an outage.[19] Because animals are usually more sensitive to such poisoning than humans, birds or other pets can sometimes help to signal a gas problem.

The source of the poisoning can sometimes prove mysterious. In 1995, residents of a Brooklyn apartment building were evacuated, and one tenant died from carbon monoxide fumes apparently caused by a cable fire in a service box on the street outside.[20]

The greatest cause of poisoning deaths in the United States involves carbon monoxide poisoning from motor vehicle exhausts. Of the 11,547 unintentional CO deaths during 1979–1988, 57 percent were attributed to motor vehicle exhausts; 83 percent of those were associated with stationary vehicles. Contrary to public perception, however, most car-related CO deaths in garages occurred even though some garage doors or windows were at least partly open—a finding that raises red flags about the dangers of attached garages.

Smoke inhalation accounts for the second leading cause of CO poisoning, putting firefighters at particularly high risk. However, levels of the gas can build up from more mundane pursuits. Tobacco smoke typically contains approximately 4 percent CO, so the cumulative nature of CO poisoning explains why heavy cigarette smokers have elevated carboxyhemoglobin (COHb) levels as high as 9 percent, putting them at greater risk of CO poisoning from other sources as well.* Urban environments have higher ambient CO concentrations than rural settings.[21]

In the late 1930s, research established that 5 percent of the nation's automobiles and closed trucks contained hazardous levels of carbon monoxide, and scientists at the Harvard Fatigue Laboratory explored the effects of the gas on six human guinea pigs who volunteered to participate in a series of experiments. None of the subjects showed any decrease in skill, even when their blood was about one-third saturated with carbon monoxide and they were practically ready to collapse. Although carbon monoxide was known to be a leading killer, little was done to prevent the hazards it posed.[22]

By the late 1960s it was clear that carbon monoxide emissions from automobiles were responsible for a large and increasing volume of the nation's carbon monoxide pollution and also posed a serious threat to public health. In 1970, Congress established the Environmental Protection Agency (EPA) with the responsibility for regulating motor vehicle pollution, and in 1990 Congress enacted the Clean Air Act. The approach has significantly reduced carbon monoxide emissions. EPA emission standards in the early 1970s forced American automakers to equip most new cars with catalytic converters designed to convert carbon monoxide to carbon dioxide. Today's passenger cars emit 90 percent less carbon monoxide over their lifetimes than their counterparts of the 1960s. The changes in car design have reduced ambient carbon monoxide levels, despite major growth in the number of vehicles on the road and a huge increase in miles

*Cigarette smoke contains over 4,000 chemicals, including 43 known carcinogenic compounds and over 400 toxins. Among the ingredients are carbon monoxide, hydrogen cyanide, arsenic, and methyl isocyanate, as well as nicotine, tar, benzene and butane, according to the American Cancer Society.

driven. But experts have said that carbon monoxide levels will rise again unless automakers institute even more effective emission controls.[23]

War poses another great danger of carbon monoxide poisoning. Most of the 135,000 Germans who died during the Allied firebomb raids of Dresden in World War II succumbed from inhaling hot gases and by CO and smoke poisoning. During fiery attacks, some Germans considered their air raid shelters even more hazardous than their streets; at least if they ran outside, the gases were not as likely to suffocate them.[24] In nuclear war, carbon monoxide kills many of those who survive the initial blast.[25]

Carbon monoxide has never appeared very useful as a chemical weapon on the battlefield, however. In World War I, military commanders opted not to use it as a war gas, for several reasons. Its temperature of liquefaction made it unsuited for use in shells or bombs. Also, its weight being only slightly less than that of air kept it from rolling into trenches and dugouts and caused it to raise rapidly into the atmosphere once it was released. Finally, its toxic value was lower than that of other gases, being, for example, one-fifth as toxic as phosgene. Only acute carbon monoxide poisoning was sufficient to kill or disable the average soldier. Many commanders learned the hard way that carbon monoxide poisoning constituted more of a hazard to one's own troops: as in civilian life, it more often caused accidental casualties in confined caves, bunkers, ships, submarines, tents, and mines.[26]

In warfare, CO's greatest impact occurred when the Nazis used it in the Action T4 "euthanasia" program and Operation Reinhard extermination camps, pumping fumes from engines or canisters into crowded vans or gas chambers to murder millions of hapless prisoners. (See Chapter 8.) Four Nazi death camps claimed as many as one million Jews and Gypsies by carbon monoxide alone.

In war or peace, carbon monoxide has proved to have such varied uses that many methods of commercial production have been developed. It has multiple applications in bulk chemicals manufacturing, coal-to-petrol conversion, and other industrial uses. Recent medical research at the University of Michigan Cardiovascular Center found that inhaling a small amount of the gas under controlled conditions could surprisingly serve as a lifesaver for patients recovering from organ transplants, strokes or heart attacks.[27]

Although carbon monoxide is associated with industrial age pollution, it has always been present in the atmosphere, chiefly due to volcanic activity. It also occurs naturally in brushfires. The extent of natural emissions of the gas is extremely variable and difficult to measure accurately. Environmental scientists now report that through natural processes in the atmosphere, most carbon monoxide is eventually turned into carbon dioxide; therefore it is a significant contributor to the greenhouse effect and global warming.

Since 2000, NASA's Terra spacecraft has been producing the most revealing long-shot picture of the world's air pollution as it appears in the troposphere (the lowest region of the Earth's atmosphere). Terra carries a global air pollution monitoring system known as MOPITT (for Measurements of Pollution in the Troposphere), that makes long-term global observations of air pollutants such as carbon monoxide, carbon dioxide, methane and ozone as the craft circles the Earth, 16 times every day. MOPITT's eye in the sky assesses the movement of carbon monoxide in the troposphere, two to three miles above the surface, where it interacts with other greenhouse gases. MOPITT's extraordinarily sophisticated instruments have helped to show precisely how CO concentration in the troposphere contributes to the greenhouse effect. Examples of MOPITT's graphic images, captured in wintertime, show the CO emitted by burning fossil fuels from home heating, mass transportation, and industry as it wafts over across much of Northern Hemisphere, and the effects of large-scale biomass burning.

According to MOPITT's principal investigator, John Gille, stationed in Boulder, CO: "With these new observations you clearly see that air pollution is much more than a local problem. It's a global issue." Gille told an interviewer, "Much of the air pollution that humans generate comes from natural sources such as large fires that travel great distances and affect areas far from the source."[28]

Chapter 11

Radon (Rn): Out of the Basement

Stan Watras said goodbye to his family and left their home in Boyertown, Pennsylvania for work as usual that fateful December day in 1984. His eight-mile drive to Pottstown was uneventful, and nothing out of the ordinary occurred at his job, where he worked as a construction engineer at the soon-to-be-opened Limerick Nuclear Power Generating Station—until he was leaving the job for the day. Then it happened.

As Watras was exiting the facility in the required manner through the portal radiation-detection monitor, the plant's alarms suddenly went off. Sirens screeched, red lights flashed. At first, the machine readings did not raise much concern for it seemed that with no nuclear fuel on site yet there was not any obvious source of radiation at the plant to be worried about. As a result, everyone assumed the strange readings reflected a glitch in the equipment: a false alarm. Nevertheless, safety procedures always required a careful response.

But as the same scenario was repeated into a second week, the situation became very annoying. Each time the alarm went off, Watras had to remove his clothes, have them washed, and then take a shower in order to decontaminate himself. It was all extremely time consuming. Then, as he prepared to leave again the next day, the alarm would go off again.

Watras was the only person singled out. Each time, the readings indicated he was highly contaminated with radiation throughout his entire body. The implications troubled him. He began to wonder if he could have been exposed somewhere else. But where?[1]

Finally, out of frustration, Watras devised a simple experiment. The next time he arrived for work he walked in the plant entrance, then immediately turned around and exited through the portal monitor. Once more, the alarm went off. Noting he had been decontaminated the previous evening, Watras now reasoned he had proof that something on his person or his clothes was responsible. He worried about possible radiation in his home.

But where could it be? The modest family house seemed innocuous enough. It had been built in 1977, and nobody knew of any likely hazards nearby. Finally, Watras convinced the higher-ups at work to send someone out to check his residence. Three power-company technicians showed up with a collection of survey instruments and grab sampling equipment. As soon as they entered the premises, the instruments went crazy. But there were no specific hot spots; instead, the readings indicated radioactive activity throughout the entire house, with the most activity in the basement. The team took these samples to the chemistry lab, and Watras and his family waited for the results.

What they found alarmed everyone. The findings showed the family's house was highly contaminated with background radiation from radon gas. State officials were called in, and they confirmed the results: the house contained thousands of picocuries of radon per liter of air—a worrisome finding, given that 4 picocuries of radon per liter of indoor air is roughly equivalent to receiving 200 chest x-rays per year. Put another way, living in the house carried as much health risk as smoking 135 packs of cigarettes every day. What was going on—and what the hell was radon?[2]

Radon is an odorless, tasteless, naturally occurring noble gas (along with helium, neon, argon, krypton, and xenon). It is also one of the heaviest gases ever discovered. The fact that radon is formed by the decay of radium means that it is radioactive and carcinogenic.

Boyertown is located in the rural countryside about 36 miles northwest of Philadelphia, more than 80 miles away from the Three Mile Island Nuclear Power Plant that had leaked five years earlier. Geologists observed that the home was located at a distinctive granite formation known as the Reading Prong. Some of the rock contained up to 80 ppm uranium, as much as 20 times the typical level.

Noting that the Watras site had radon concentrations that were 650–1,000 times greater than normal, scientists pointed out that radon can flow for many miles underground before rising to the surface through faults and porous rock that is far from its source. They theorized that naturally occurring, radioactive radon gas had seeped into the building from subterranean sources in large enough quantities to pose a serious health danger.

Technicians at New York University Medical Center performed radiation scans on each member of the Watras family, looking for Pb-210 accumulation in bone. To their distress, the highest accumulation was found in the baby; this was followed by Mrs. Watras and their son Mike. Mr. Watras actually had the lowest reading, even though he was the one who had first set off the alarms. Fortunately, the family had lived in the house for only one year, so their exposure was not long-term, and it was unclear how long the radon levels may have been that high or low. Therefore, the damage to their health was unknown. But everyone was worried.

It began to sink in that Watras and his family were living in a radiation-contaminated environment. Ironically, Watras had not been carrying radiation from the nuclear plant to his house—it was the other way around. When it was clear that dangerous levels of radon gas had contaminated their house, the Watras family was advised to move to another location, which they did, uprooting to a local motel until they rented another house as they awaited further studies of their home.

Soon the news media got hold of it, and their radon ordeal became a big international story. Stan Watras and his house became famous, if not notorious. People avoided close personal contact with them, and the market value of their home plummeted. The episode also made radon a household word, synonymous with a previously unsuspected but apparently widespread residential health hazard.

At first, Watras had trouble finding anyone who was able and willing to help him try to fix his residence. Eventually, the plant owner, Philadelphia Electric Company (PECO), and the Bureau of Radiation Protection decided to undertake the costly remedial work on an experimental basis. The plans entailed extensive excavation, installation of a radon/waterproofing system, landscaping, venting and sealing, pouring of a new concrete floor, and other renovations. Pipes were installed under the foundation to draw off the radon. Seven months later, the remediation efforts at the site proved so successful that the Watras family was able to move back into the house safely. (The family still occupies the residence to this day—proof that radon can be removed from a building.) But the urgency for others to learn more about radon's effects was just beginning.[3]

The history of radon dates back to 1896, when a French scientist, Antoine Henri Becquerel, was preparing to conduct an experiment involving a strange fluorescent mineral, thought to be potassium uranyl sulfate. Becquerel inadvertently left some of it atop an unexposed photographic plate in one of his darkened laboratory drawers. He later discovered that the image on the plate had become fogged as if it had been partially exposed to light. After considering the possibilities he reasoned that some form of invisible rays or light emitted by the substance may have somehow fully exposed the plate. Becquerel's discovery of uranium had led him to stumble upon the concept of radioactivity, for which he would receive the Nobel Prize in 1903.

In 1900, Friedrich Ernst Dorn, a German physicist at Halle University, discovered a very heavy radioactive gas coming from uranium or radium, which he called radium emanation. In 1908 William Ramsay and Robert Whytlaw-Gray isolated the gas and determined its properties. (In 1923, others named it radon.)

Scientists have since determined that radon has existed as long as the earth itself. Archaeologists have determined that uranium was used as early as 79 CE, when the Romans utilized it to add yellow color to their ceramic glazes. In the Middle Ages, some of it known as "pitchblende" was extracted from Bohemian silver mines to serve as a coloring agent for glassmakers. But the artisans did not grasp what they were handling.

Archaeologists have uncovered evidence that thermal springs containing radon gas existed in Bad Gastein, Austria, as long as 6,000 years ago, and on the island of Ischia near Naples as far back as 500 BCE. Although the ancient Romans did not understand what it was, they believed in radon's healing effects and established baths there. During the Middle Ages, water from the Bad Gastein baths was directed into enclosed bathtubs. The physician Paracelsus (1493–1541) tried to determine if Bad Gastein's thermal waters actually had any therapeutic value, but he could not reach any firm conclusion. In the early twentieth century, radon baths became fashionable again for health and recreational purposes in Europe, Japan, New Zealand, and the United States. (Some of the most popular American radon spas have included Saratoga Springs, New York and Hot Springs, Arkansas.) To this day, some users swear by their beneficial effects for treating arthritis, asthma, and other painful inflammatory ailments, although many medical authorities continue to question such claims.[4]

But radon has also long been linked to health problems. For centuries, miners in Bohemia complained of pulmonary diseases, known as "mountain sickness," which many attributed to the inhalation of some sort of poison vapors. Starting in the 1930s, medical researchers began to connect link radon to cancerous lung tumors of uranium miners in Bohemia. After the end of World War II, as uranium attained great importance due to its use in nuclear engineering, further studies noted health problems among Native American and Mormon uranium miners in the Southwestern United States. Scientists determined that it was radon decay products that delivered the most harm to the lungs. By the late 1950s, government researchers had started to recognize the problem of lung cancer and resulting deaths among uranium miners. Beginning in 1959, the U.S. Public Health Service warned miners about the hazards of radon exposure. In 1967, the federal government set the first radon safety standard for mining.[5]

Radon fallout and pollution is known to have happened as a result of several known major nuclear accidents, including the Windscale fire at the Sellafield, England nuclear reactor in October 1957, the Three Mile Island accident in Pennsylvania in 1979, and the Chernobyl disaster in Ukraine in 1986. In the wake of the Three Mile Island accident, extremely high radon concentrations were later detected in counties surrounding the troubled plant. But the extent of radon contamination from "healthy" nuclear facilities has not received much public notice.

Normal operation of a nuclear power plant produces radon, some of which leaks out of the fuel and into the cooling water. After the radon is removed from the water, it is routed to a holding tank where most of it must remain and remain and remain for a large number of half-lives. In the past, some radon was routinely released into the open air through a tall stack, at radiation levels that were closely monitored. But since environmental scientists have become more alarmed about the long-term effects of radon's pollution of the atmosphere, more geothermal power stations have increasingly resorted to pumping the radon deep underground, where it has ended up in the soil or water.[6] Now that practice is also suspect.

The nuclear age has drawn attention to health and environmental dangers of radioactive fallout from uranium daughter isotopes. Some studies have suggested that every living person in the world today as well as those who will live during the next tens of thousands of years will carry minute traces of radioactive elements from nuclear tests that have already taken place; such testing is blamed for having contributed to human cancers and leukemia.[7]

Government officials now report that radon gas and its solid gas decay products cause cancer. Yet the extent of radon's problem as a carcinogen has only lately begun to sink in. Medical studies reveal that radon decay products can be inhaled into the lung, where they continue to decay, releasing small bursts of radioactive energy that can damage DNA. Since radon gas can show up and accumulate in buildings, the gas is blamed for 15,000–22,000 lung cancer deaths per year in the United States alone. The National Academy of Sciences has cited radon as the second most frequent cause of lung cancer (after cigarette smoking) in the United States, and radon-induced lung cancer is rated as the sixth leading cause of cancer death overall, making it even more deadly than secondhand cigarette smoke—astonishing facts when one considers that public consciousness regarding radon remains so low compared to awareness about secondhand smoke. According to the National Cancer Institute and the Surgeon General of the United States, radon-induced lung cancer presently claims 20,000 lives per year in this country. Worldwide, radon is blamed for 15 percent of all lung cancers.

The EPA says radon's greatest health risk for humans comes from the inhalation of solid radon decay products. Radon decay produces radiation and radon progeny (daughters). These daughters are composed of minute and electrically-charged heavy metal particles of lead, polonium, and bismuth. As the tiny particles float in the air, some can get inhaled and land in the lungs, where they become lodged, causing damage as they continue to undergo radioactive decay. In order to contract lung cancer, it is not necessary for a person to inhale a large concentration of radon; all it takes is a single radon atom. Moreover, radon particles can also alter a cell's genetic material or DNA. Some damage may result in cancerous tumors.

Radon's link to lung cancer is well established, but it is not yet clear whether radon causes other types of cancer. Much has been learned in the last 20 years, but research and education on the health effects of radon still has a long way to go.[8]

Radon is not limited to the United States. Some of the highest readings ever recorded have occurred in the town of Mallow in County Cork, Ireland. In the United States, however, the discovery of dangers lurking in the Watras home triggered a nationwide look into radon hazards that found them in every state. Besides being particularly prevalent in the Reading Prong of eastern Pennsylvania, high radon levels were also found in rocky coastal Maine and along parts of northern New Jersey and New York. The highest statewide average radon concentrations are found in Iowa, where a whopping 70 percent of short-term screening measurements registered over the EPA's action level.

The EPA estimates that nearly 1 out of every 15 homes in the U.S. has indoor radon levels at or above the level that warrant remedial action. (That level is 4 picocuries per liter of air per year.) Hazardous levels have also been detected in many schools and offices. Radon's occurrence is so widespread and variable that the EPA and the U.S. Surgeon General both have recommended that every house in America be tested. The detection of radon gas requires special devices. And a negative test result does not guarantee that a radon problem will not occur in the future. Repeated measurements may be advised.

The good news is that inexpensive, commercially sold test kits are available to determine radon levels in buildings. Radon levels fluctuate with weather conditions and other factors. Increased ventilation and improved construction features can greatly reduce the concentration of the gas.[9]

Much more remains to be learned. But radon remains one of the most underrated and neglected lethal gases in the world today—a mass killer that has been lying low.

Chapter 12

ACCIDENTS AND DISASTERS

As crude a weapon as the cave man's club, the chemical barrage has been hurled against the fabric of life.

—Rachel Louise Carson, *Silent Spring* (1963)

Lethal gases account for a significant share of the accidental deaths and injuries that occur in the world. Fires, for example, cause damage by various means, including heat, smoke, and water. But toxic gases from burning materials constitute one of the most harmful fire-related hazards. Some of the toxic gases released by fires commonly include carbon dioxide, carbon monoxide, sulfur dioxide, hydrogen cyanide, hydrogen sulfide, hydrogen fluoride, and ammonia, to name a few. The harmful gases from ordinary cigarette smoke constitute another leading health danger.[1] Besides the harmful toxic gases produced by fires and smoking, many additional non-fire accidental carbon monoxide fatal poisonings are attributable to automobiles, heating systems, and gas ranges and ovens. Accidental carbon monoxide intoxications are responsible for more than 15,000 visits to hospital emergency rooms annually.

For the purposes of this discussion, it is also instructive to note the deleterious effects of chlorine gas released from accidental industrial leaks—a problem that has existed for more than 50 years. In 1947 a leaking cylinder containing 40 kg of liquid chlorine was blamed for 418 casualties in Brooklyn. Although no immediate deaths resulted, at least 208 persons required hospitalization. Some of the most severely affected suffered acute respiratory distress; 33 were diagnosed with tracheobronchitis, 23 had pulmonary edema, and 14 contracted pneumonia.[2] There was no follow-up study to check for possible long-range health effects.

In January 2005, at least 9 people were killed and 234 persons were hospitalized after a freight train derailed in the tiny town of Graniteville, South Carolina, causing the rupture of a highly pressurized tank containing 90 tons of deadly green liquid chlorine. The liquid turned into gas. Six of the deaths were attributed to acute chlorine inhalation. The toll likely would have been higher had authorities not ordered everyone within a one-mile radius to evacuate the area.

Emergency crews used plastic sheets to temporarily stop the leak and pumped sodium into the leaking tank to dilute the toxicity of the remaining 30 tons of chlorine. The crash site was just 20 minutes away from a federal nuclear research and storage facility. Another train crash had occurred at the same location only two months earlier, killing five local workers.[3]

Most chlorine exposures result from storage or transportation accidents involving pressurized liquid chlorine. Other chlorine poisonings commonly occur in industrial accidents, swimming pool spills, and other mishaps.[4] Because chlorine remains such a staple in modern society, there are many opportunities for misuse.

After World War I, the chemical industry also found many more industrial uses for deadly phosgene. Germany, the United States, and other nations continued to produce it in large quantities. But the manufacturing occasionally reminded everyone of its lethal qualities. On the morning of April 22, 1921, a phosgene leak in the Hemingway plant of the Sherwin-Williams Paint Company in Bound Brook, New Jersey, threatened for a time to wipe out the whole town as workers in gas masks scurried to repair the broken valve. One person was killed and more than 100 were injured. In 1928, a phosgene leak in Hamburg, Germany was responsible for at least 10 deaths and hundreds of injuries.[5] Such accidents continue to occur to this day, another example being a phosgene leak in East China's Fujian Province in 2004 that resulted in at least one death and more than 100 reported injuries.[6] The worst disaster occurred at a pesticide factory in Bhopal, India.

METHYL ISOCYNATE (MIC)

Bhopal Remains the Worst Plant Accident in History

A tragedy of hideous proportions shocked the world more than two decades ago. Twenty-five years after the worst industrial accident in history, Bhopal continues to exemplify just how bad a lethal gas disaster can be. Yet its impact has become even more severe over time, becoming what some observers have called the "Hiroshima of the chemical industry."[7] Today Bhopal still raises vexing questions about the implications of globalization, corporate accountability, government regulation, scientific and industrial responsibility, society's failure to protect health and the environment, the bankruptcy of the legal system, and the need to address the long-term deleterious effects of harmful pesticide chemicals.

The catastrophe occurred in Bhopal, a city of about 600,000 persons, located in the heart of India. In an effort to help feed the world's second most populous nation, the Indian government in the late 1960s and early 1970s had encouraged the use of pesticides as a means of increasing self-sufficiency in agricultural production among the country's 400,000 farmers. Something had to be done to keep the insects from devouring their crops. In 1969, Union Carbide established a small pesticide manufacturing plant on the outskirts of Bhopal, based on its proximity to a railway, water, electric power, and cheap labor.[8] By 1979, the factory was converted to manufacture methyl isocyanate (MIC), one of many key intermediate chemicals used in deadly pesticide production.

Although nominally a clear, odorless, colorless liquid at room temperature, MIC evaporates so quickly from an open container that it easily turns into a highly flammable and highly reactive gas. Its low flash point requires it to be stored at temperatures near zero degrees centigrade. MIC also reacts quickly with water, which poses further hazards. The fact that it can easily be inhaled or absorbed through the skin makes it especially dangerous to humans. Persons who inhale MIC often feel burning in their nasal passages, throat, and trachea, and their lungs fill with fluid, causing them to suffocate, or they can suffer severe liver damage. According to the Centers for Disease Control, toxicity typically develops within one to four hours after exposure. The signs and symptoms of methyl isocyanate poisoning include cough, dyspnea, chest pain, lacrimation, eyelid edema, and unconsciousness. Severe MIC poisoning can lead to acute lung injury, cardiac arrest, and death.[9]

Some observers have labeled MIC one of the most dangerous substances ever invented by the chemical industry; they also note that it is usually manufactured from phosgene, one of the most deadly war gases used in World War I.[10] Phosgene (or carbonyl chloride) is a colorless, highly toxic gas. It was first synthesized in the nineteenth century and used in deadly chemical warfare attacks during World War I. (See Chapter 5.) After the war the chemical industry began using it on a large scale in the manufacture of dyes, resins, and pesticides, which eventually included MIC. Although the effects of exposure to MIC can be treatable, exposure to even a small dose of phosgene can prove lethal.

The Bhopal plant was in the business of manufacturing carbamate pesticides. Like the Nazi nerve agents invented in World War II, carbamate insecticides are inhibitors of acetylcholinesterase, but unlike the organophosphates such as tabun or sarin, their actions are considered reversible.

Union Carbide needed MIC to help produce its popular pesticide Temik, a highly effective but controversial insecticide used to increase crop yields. Temik is an aldicarb chemical that is rated 307 times more lethal than the carbaryl sevin it is also used to produce. By the early 1980s Temik was being blamed for a host of problems. On Long Island, where it had been used on potatoes, it had filtered down into ground water, thereby contaminating thousands of wells. Temik's use was already banned or restricted in New York, Rhode Island, Florida and Wisconsin. In California and Canada some persons who ate Temik-contaminated watermelon suffered from flu-like symptoms such as nausea, shortness of breath, dizziness, shaking, vomiting, blurred vision and muscle weakness that many attributed to one of Temik's active ingredients, aldicarb.

Some pregnant women who had been exposed to Temik claimed it had caused them to give birth to stillborn infants.[11] The Bhopal plant also produced Sevin.*

Production of the poisons was a dangerous business. Although the Bhopal facility was nearly identical in design to Union Carbide's MIC-manufacturing plant in Institute, West Virginia, the company operated its India business under far less stringent environmental and safety standards than those found in the United States. In India the company had eliminated many of the safety features and procedures as a means of cutting as many corners as it could in order to maximize profits. Some of these differences included the following: unlike the West Virginia situation, Bhopal often had large quantities of MIC stored for long periods. Its storage tank was not equipped with emergency scrubbers that could neutralize any escaping MIC, and the plant's primitive monitoring instruments, lacking any computerized capability, relied entirely on manual observation. Instead of using chloroform, the cooling system was based on brine, which was highly reactive with MIC; furthermore, Bhopal's erratic refrigeration unit for cooling the temperature of the chemicals in tanks had been turned off six months earlier. As a result, the stored contents were highly reactive. Bhopal's tanks had not been under nitrogen pressure for two months, which added to the hazard. Yet the plant had no system in place to inform the local authorities or the people living adjacent to the plant of any danger; there was no emergency plan shared with local officials; and the only way for the plant to warn the public was through a loud siren. Alarm systems and other instruments had not been tested or properly maintained. Plant personnel were not properly trained or equipped with adequate safety gear, and there were other deficiencies.[12]

Knowledgeable Indians feared the Union Carbide plant was a ticking time bomb. Several workers had become sick from their exposure to various chemicals, and on the day after Christmas in 1981 a maintenance worker, Ashraf Lala, was killed by the release of a few drops of phosgene onto his sweater that vaporized and which he subsequently inhaled into his lungs. The workers' unions had begun to agitate for safer working conditions, but the company resisted. [13] Leaks and other accidents continued to cause more serious injuries. In 1982, a local journalist wrote a series of articles in the *Rapat Weekly*, some of which were headlined, "BHOPAL SITTING AT THE EDGE OF A VOLCANO," and "BHOPAL ON THE BRINK OF DISASTER," in which he begged the city to take notice of the dangers posed by the pesticide factory. "For now Bhopal sleeps," Rajkumar Keswani wrote, "till the next morning and possibly to never get up some morning."[14] The clamor spurred Union Carbide to send in an

*MIC is also an intermediary in the production of the pesticide Sevin (carbaryl), which is sold in Home Depot and other stores, marketed by the Bayer Company. Sevin ranks third among all insecticides in U.S. domestic sales. The poison is widely used in commercial agriculture, forest and rangeland protection, and home-and-garden pest control. Some critics link its rampant use to destruction of the honeybee and other ill effects. See the CDC's occupational health guideline for Sevin at http://www.cdc.gov/niosh/docs/81-123/pdfs/0100.pdf.

inspection team. The team's internal safety audit documented 61 hazards, of which 30 were classified as major. Eleven of the worst involved the dangerous phosgene/MIC units. Its report warned the company about the "potential for the release of toxic materials" and a consequent "runaway reaction" due to "equipment failure, operating problems, or maintenance problems." But management's only response was to make further cutbacks of 335 men that were designed to save the company $1.25 million that year.[15] As a result, the problem became worse. The deadly chemicals just sat there, stewing.

On the night of December 2–3, 1984, a dangerous series of events began to unfold at the plant after a water-washing exercise that began at 8:30 P.M. A large amount of water contaminated with iron rust, and sodium and chloride compounds had blocked some of the pipes and gotten into the MIC storage tank #610, which contained about 42 tons of MIC. Because the tank was 80 percent full and the chemical was at a high temperature, it did not take long for pressure to build and the release to take place. The blockage set off an exothermic reaction that caused catalytic trimerization, forcing a sudden leak of the toxic gas. At 11:00 P.M. the control room operator noticed a sudden rise in pressure, but he did not know the gravity of the situation or how to respond to contain it. Workers were not aware of the leak until their eyes suddenly began to tear and burn.

Warnings were quickly sent up the chain of command, but the higher-ups were slow to respond. According to a subsequent investigation report: "At 12:20 A.M. the MIC Production Supervisor notified the Plant Superintendent of the release. The Plant Superintendent, who was in the formulations area, arrived in the MIC Unit around 12:25 A.M. and found much MIC in the atmosphere . . ." At around 12:30 the concrete casing of tank 610 split in two, and both the rupture disk and the safety valve popped, releasing more of the contents of MIC into the ground and air. At 12:45 the Derivatives Unit operations were suspended due to the high concentration of MIC in the area. Suddenly the air smelled of freshly mowed grass, boiled cabbage, and ammonia. At 12:50 a Derivatives Unit operator finally broke the glass of the Toxic Gas Alarm, starting the loud factory siren that was the only means of warning the other workers and summoning the rescue squad.[16]

In response to the screaming siren, the rescue squad hurried to the plant and tried to stop the toxic release of MIC. But soon they and other workers frantically fled the area in the opposite wind directions. Some of the men cried out for everyone to get out of the area. But nobody realized how badly the gas would affect neighbors downwind.

By that time, about 40 tons of mostly white MIC gas and unidentified reaction products had poured out of the tank and escaped into the air, to be carried southward by the wind over an area of about eight kilometers. The gas formed into a low-hanging cloud made up of several layers. The heaviest layer, MIC, rolled over the ground, while the higher layers were made up of phosgene, hydrocyanic acid, monomethylamine and other gases. The deadly gas cloud slammed through a belt of crowded slums housing thousands of migrant workers and their families who lived in shacks without doors or windows, and some of it seeped into the more substantial homes. Most residents were asleep in their huts when it struck. Many would never wake up.

The first official to sense that something horrible had occurred was a police officer on night patrol, who at 1:15 encountered crowds of hysterical people fleeing their homes. He noticed many were coughing, screaming and rubbing their eyes. At 1:20 he radioed the information to the Police Control Room, prompting the police magistrate to telephone the factory Works Manager at his residence and ask him about the problem. But the manager was unaware of any toxic leak, and he suggested that anybody with eye irritation should thoroughly wash their eyes with water. The manager never mentioned what deadly gases were involved or what other perils might ensue.[17]

Bhopal was suffering a terrifying attack at the worst possible time. One local resident, Aziza Sultan, was awakened by the sound of her baby coughing. "In the half-light," she said, "I saw that the room was filled with a white cloud. I heard a lot of people shouting. They were shouting 'run, run'. Then I started coughing with each breath seeming as if I was breathing in fire. My eyes were burning."[18]

Across the road from the factory, in the impoverished Jai Prakash Nagar settlement, Puna Bai, a young mother of three, became aware that her husband had gotten out of bed to drink some water and started coughing. Soon she began to hear screams and commotion coming from outside. Then some sort of smoke began entering their house and everyone started coughing; the kids were complaining that their eyes were burning. "Then we heard someone saying that we should all run because some gas pipe had exploded in the Union Carbide factory," she later recalled. "We all started running and eventually I got separated from my family. I just remember not being able to locate my family and then after that I had lost consciousness."[19]

Blinded by the dense cloud enveloping their neighborhood, the residents lost sight of their loved ones and tried to cover their eyes and mouths, gasping for breath. Bodies around them were shaking with spasms. Some lost control of their body functions and had urine and feces running down their legs. Pregnant women felt their unborn babies slipping from their wombs. One of them, Tarai Bai, was three months pregnant when she lost her fetus as she fled the lethal cloud, screaming and choking as the gas burnt her lungs.[20]

The fatal airs continued to pour through several of the nearby shantytowns, affecting thousands of victims. Roused from their sleep, the residents felt the burning as if hot chilies had infested their eyes, throats and lungs. Victims writhed in agony. Many continued to cough and vomit blackish clots as they staggered through the streets or fell down with contorted faces. Some who had been roused and tried to flee screamed with horror as the cloud overtook them. The streets were littered with dead animals and human corpses. At the train station the deputy station master looked out of his office to see passengers on the platform wracked with coughing, and hearing some of the reports, he desperately tried to prevent the next approaching train from stopping and opening its doors. Alarms and shouts cascaded through the city.[21]

Within hours, all of Bhopal's medical clinics and hospitals were jammed with suffering victims and corpses, leaving the beleaguered doctors and nurses to try one ineffective treatment after another, since they did not know what chemicals were involved or what, if any, antidotes might work. Company officials refused to reveal anything about the gas. As many as 4,000 or so persons perished before breakfast time, and over the next few days the death roll rose to 7,000–10,000 or more. It would not be until months or years later that others learned they had suffered permanent damage to their lungs and other organs. The first night was only the first installment of their nightmare.

Most of the dead had succumbed to cardiac and respiratory arrest. A physician who performed over 100 autopsies at Hamidia Hospital in the days following the disaster reported finding "a gross increase in the weight of the lungs of up to three times the normal. The entire respiratory tract showed pathological changes. The lungs were heavily water-logged and had a distinctive cherry-red colour. . . . The mucosa was intensely congested. The trachea and the major divisions of the bronchi revealed necrotizing or ulcerative changes."[22]

In the hours and days that followed the leak, thousands of bodies of dead persons and animals lay in heaps in the streets. Vegetation hung yellow and wilted. Parts of the Betwa River were jammed with corpses. There were so many dead bodies lying about that the army took to dumping hundreds of carcasses in the surrounding forests, making it even more impossible for anyone to ever compile an accurate tally of the fatalities.

Twenty years later, Amnesty International estimated the number of Bhopal's casualties at 7,000 dead in the first few days, another 15,000 over the ensuing years, and more than 100,000 injured by debilitating illnesses for which there was little or no treatment. More than 520,000 persons in 36 wards had been exposed to the toxic gas, and two wards holding more than 32,000 persons had been severely affected. Three thousand of them were pregnant, and 200,000 were under 15 years old.[23]

At first company and government officials offered no explanation for what had occurred, and residents were simply told to return to their homes. There was no evacuation, decontamination, or effort to bring in clean food or water.

However, the day after the leak, Union Carbide's CEO, Warren Anderson, left his corporate headquarters in Danbury, Connecticut and flew to India on his Gulf Stream II twin-jet plane to assess the situation. Arriving in Bombay on Thursday, December 6 at 5 A.M., he was whisked away to a luxury hotel where he could rest and begin to meet with company and government officials. The next day Anderson was flown to Bhopal, where a contingent of police immediately took him into protective custody. As the company's chief executive entered the grounds of the Union Carbide research facility, he was placed under arrest. News of his treatment flashed across the globe. Anderson ended up being held for a few days until his lawyers had arranged a bail hearing.

"Mr. Anderson, are you prepared to come back to India to answer any legal charges?" he was asked.

"I will come back to India whenever the law requires it," he replied.

With that, Anderson was released on bond on the condition that he would later return to face charges. After being charged with culpable homicide, he never returned to India as promised, however, and the Indian government's request for extradition was never honored by the United States. As a result, to this day he remains a fugitive from justice, living lavishly in several homes in New York and Florida.[24]

Bhopal's victims and their advocates tried to gain redress through the courts of India and the United States, without much success. In 1989 the Indian Supreme Court endorsed a controversial settlement requiring the Union Carbide Corporation (UCC) to pay $470 million for the victims. But even that grossly inadequate sum was not distributed to the victims. As of 2001 the average victim's payout totaled only $580. Twenty years after the disaster, the Indian government had rejected about 30 percent of the claims for injuries, and 16,000 more were outstanding; even the successful applicants had received only a pittance of compensation. The process was moving so slowly that the Reserve Bank of India continued to hold $330 million of the $470 million alloted.[25]

Ever since the catastrophe began to unfold, activists have struggled to alleviate the victims' sufferings and require corporate and government officials to assume responsibility for their negligence. One of the leaders of this movement has been Sathyu Sarangi, a former mechanical engineer who since the day after the leak has devoted his life to helping the survivors. Among those leading hunger strikes, marches, and other actions have been Tarai Bai, a mother who lost her unborn baby during the accident, and Rashida Bee, who lost five members of her family during the fatal night. Several U.S.-based organizations have also been formed to support the Bhopal victims.[26]

Since merging with Union Carbide in 2001, Dow Chemical had not done anything more to live up to its corporate responsibilities for the tragedy. Then suddenly in 2004 the British Broadcasting Company broadcast a report that the company had finally done the right thing by taking "full responsibility" for Bhopal. "Jude Finisterra," an individual identified as a spokesman for Dow, went on the World News to say the company had decided to liquidate Union Carbide for $12 billion in order to pay for medical care for the victims, cleanup of the toxic chemicals, and to support research on the hazards posed by other dangerous Dow chemical products. A burst of favorable coverage ensued and Dow's actions were greeted with applause—until the firm issued a press release calling the statement a hoax. The corporate embarrassment was later traced to The Yes Men, a group of anti-corporate human rights activists who had hatched the ruse as a way of drawing world attention to Dow's failure. Their stunt briefly helped to refocus media attention on the continuing outrage inflicted on Bhopal.[27]

In fact, the plant site had not been cleaned up at all. In 2004, reports by Bhopal community groups and Greenpeace documented that the abandoned factory still contained large stockpiles of toxic pesticides (including Sevin and hexachlorocyclohexane); the site was also littered with hazardous wastes and contaminated material. The survey found much of the area's land and water supplies remained plagued by substantial to severe contamination from heavy metals and chlorinated chemicals. Samples from wells around the site showed high levels of chloroform, carbon tetrachloride, and other toxic chemicals; some concentrations were more than 600 times the limits recommended by the EPA. The primary water supply of more than 20,000 Bhopal residents had become poisoned with toxic chemicals that were probably carcinogenic.[28]

Today, more than 25 years after the worst industrial disaster in history, Bhopal's legacy continues to fester. The tragedy continues.[29]

Chapter 13

Worst Gassing since the Holocaust: Mustard, Tabun, Sarin, VX, Cyanide

In the final months of the Iran-Iraq War that would end up taking 1½ million lives from 1980–88, an event happened in northern Iraq that became seared into the history books as one of the era's most despicable episodes involving lethal war gases. It occurred in Halabja, located about 15 miles from the Iran border. Halabja was also home to about 70,000 largely secular Kurds—members of the Middle East's largest and most oppressed stateless ethnic minority, who were renowned for resisting allegiance to any foreign regime, be it Iranian, Turkish, or Iraqi. Most residents considered themselves citizens of Kurdistan, not subjects of Iraq or Iran, putting them in the middle of the two warring countries. Due to their defiance of the tyrannical regime of Saddam Hussein, however, Halabja was marked for vengeance.[1] Many residents expected an attack, but they did not dream it would ever take such a hideous form.

Late in the morning of March 16, 1988, some residents observed a lone Iraqi Air Force helicopter flying low over the city taking video. Then, shortly before 11 A.M., the Iraqi Army stationed nearby commenced a thunderous artillery bombardment of the city. Rockets, shells, and bombs rained down. As terrified residents rushed into their homes or government-built shelters, high-shrapnel explosives began knocking down the roofs and windows, pocking the walls and inflicting jagged wounds on the trembling inhabitants gathered inside. Then came napalm and toxic smoke. Later, more Air Force helicopters returned and began dropping other strange objects on the town, especially over the northern area. At first the wind appeared to be carrying leaflets or balloons down from the sky; then around 2 P.M. or so, the jets began dropping pieces of metal that seemed to land without exploding, leaving the huddled residents to wonder what was going on. The sound of the attack had changed, and some of those hiding in their homes began to detect strong scents of garlic, sweet apples, rotten eggs, and gasoline.

When curious Kurds peered outside, they noticed the carcasses of birds and goats on the ground and saw other animals dying. That was when they realized something was drastically wrong with the air. Strange clouds were wafting through the empty town, penetrating the broken houses and filtering into the shelters where families cringed. People scurried in a vain attempt to fill up cracks or holes before the gas arrived. Many panicked. Mothers grabbed their babies and set off to run, with other children in tow, but some of those in flight had begun to vomit and scream; others simply dropped in their tracks and writhed in the dirt. Victims rubbed their reddened eyes and clutched their throats. Six Mirage fighter-bombers swept back and forth at 10-minute intervals, dropping their poisons and blanketing the area with deadly invisible vapors. The streets along the houses were littered with bodies, relatives clumped together in final embrace. The lucky ones fled ahead of the deadly wind and avoided gulping any of the contaminated well water down their parched and burning throats. But for some of them, too, the symptoms would take hours, days, weeks or even years to reach their full-blown phase of sores, blisters, blindness, bleeding, miscarriage, disorientation, infertility, respiratory ailments, birth defects, depression, and cancers. Years later, some of the locals would report that something about the poisons had somehow made the region's venomous snakes more deadly, whereas every other living creature had either died or suffered enormous debilitating setbacks.[2]

In the terror-stricken days that followed the chemical attack, the Kurdish spirit crumbled. The Iranian government organized media tours of Halabja to witness the devastation and took reporters and human rights observers around hospital clinics to examine the injuries sustained by thousands of survivors.[3] Photographs and videotape of poisoned victims sprawled in gutters and fields horrified the world. At first, however, officials of many Western nations including the United States blamed the chemical attacks on the Iranians, despite eyewitness and media accounts to the contrary.

But incontrovertible evidence emerged linking it to the Iraqis: markings on gas canisters, intercepted messages, confessions of downed pilots, and hundreds of eyewitness accounts. The UN Security Council censured Iraq for the Halabja attack. The U.S. Senate tried to cut off all U.S. assistance to Iraq and stop imports of Iraqi oil. But President Ronald Reagan's administration squelched the measure, claiming that Iran was responsible for the chemical attack; then the incoming George H. W. Bush administration continued U.S. support of the Iraqi regime. It was only after a British filmmaker, Gwynne Roberts, reported on the Kurds' plight that others began to take up the cause.

Halabja was neither the first nor the last example of chemical warfare attacks against the Kurds. Calls for chemical warfare against Kurdish civilians had occurred during the very origins of the state of Iraq immediately following World War I, when the Royal Air Force was sent over to quell Arab and Kurdish uprisings. In those days, then-Foreign Secretary Winston Churchill advised Great Britain to use chemical weapons "against recalcitrant Arabs as an experiment," adding, "I am strongly in favour of using poisoned gas against uncivilised tribes [to] spread a lively terror."[4]

More recently, between August 1983 and July 1988, the Iraqi military killed tens of thousands of Kurdish civilians and Iranian military with mustard, tabun, sarin and other nerve agents—not just at Halabja.* The gassings were part of an organized genocidal campaign, known as the Anfal (Arabic for "spoils of war") in which 100,000–150,000 people were systematically murdered over a period of 16 months, most of them by non-chemical means, according to estimates by Human Rights Watch and other responsible observers.[5] The slaughter was led by Saddam Hussein's cousin, Gen. Ali Hassan al-Majid, who would become known as "Chemical Ali." Some of the most damning evidence against him came from his own mouth, as he was heard spouting a tape-recorded speech to the Ba'ath Party that was later captured by rebels, in which Chemical Ali said, "I will kill them [the Kurds] all with chemical weapons! Who is going to say anything? The international community? Fuck them! The international community and those who listen to them . . . I will not attack them with chemicals just one day, but I will continue to attack them with chemicals for fifteen days."[6]

The failure of the United States to respond to Halabja was nothing new. In the wake of the Iranian Revolution and the ignominious Iranian Embassy hostage crisis, the United States did all it could to undermine the regime of Ayatollah Khomeni, especially by providing arms and other aid to Tehran's bitter enemy, Iraq. In November 1983, Reagan's secretary of state, George Schultz, had received intelligence reports that Iraqi troops were resorting to chemical weapons against Iranian forces in an effort to impede their "human wave" assaults. A month later, Reagan sent a special emissary, Donald Rumsfeld, to assure Saddam Hussein of U.S. support.[7] Rumsfeld and Saddam Hussein shook hands for the camera.

By the spring of 1984, the United States and the United Nations were well aware that Iraq was using mustard gas and other chemical weapons against Iranian soldiers. Saddam Hussein gained the dubious distinction of becoming the first national leader to use nerve gas on the battlefield—something that not even Hitler had done.[8] That July, the CIA began providing Iraq with intelligence reports, which the Iraqis used to help calibrate their mustard gas attacks on the Iranians. Despite media reports describing Iraq's chemical assaults, in March 1986, the United States and Great Britain blocked all Security Council resolutions condemning Iraq's use of chemical weapons, and on March 21, the United States refused to sign another Security Council statement condemning Iraq's use of lethal chemical agents. Barely two weeks after Iraq's chemical attack on Halabja, the U.S. Department of Commerce approved shipment to Iraq of dual-use chemicals that were used to manufacture mustard gas.[9]

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*From 1967–69, British, Canadian and American forces conducted Project 112 in which they carried out open-air tests (Rapid Tan) involving tabun and other nerve agents. But tabun was apparently never used in combat until March 17, 1984, when Iraqi forces used it in aerial bombs against Iranian troops near Basra. Iraq continued to employ tabun for a year, reportedly killing 5,500 Iranians. In 1988, Iraqi forces used tabun on civilians in the Kurdish town of Halabja. Renewed concern about its availability and health effects arose during the first Gulf War and the U.S.-Iraq War, as well as in connection with possible use by international terrorists because tabun is considered an easier nerve agent to synthesize.

And in August 1988, the Defense Intelligence Agency assisted Iraq in its last major battle of the war, in which 65,000 Iranians were killed—20,000 of them by poison gas—in violation of the Geneva Accords of 1925.[10] During the same period, of course, the Reagan-Bush administration also secretly trafficked arms to Iran to help finance its illegal support of the Contras in El Salvador, thereby working both sides of the Iran-Iraq street.

America's military support of Saddam Hussein continued as late as April 1990, when an American delegation met with him in Baghdad, and Sen. Alan Simpson (R-Wyoming), told him, "I believe your problem is with the Western media, not with the U.S. Government, because you are isolated from the media and the press." When the Kurds dispatched a senior official, Mahmoud Othman, to Washington to complain about its treatment, no one in the U.S. government would see him.[11] In fact, this American support of Iraq and its failure to roundly condemn the Iraqi dictator's war crimes in Halabja and elsewhere, did not end until Iraq invaded Kuwait, in August of 1990. But then the United States went to war.

During the first Gulf War in 1991, Iraq did not resort to using chemical weapons against the United States, Israel, or anyone else. But more than 100,000 American troops may have suffered brain damage due to low-level exposure to sarin, according to a federally funded study published in the June 2007 issue of the journal *NeuroToxicology*. The study revived years of debate over the issue of whether American Gulf War veterans had experienced injury from chemical weapons—possibly as a result of soldiers' exposure to oil well fires or the U.S. Army's own reckless explosion of huge confiscated caches of missiles containing nerve gases that had taken place at a massive ammunition dump in Khamisiyah, Iraq in the war's immediate aftermath. Shortly after returning home, nearly one in seven of the 700,000 U.S. troops deployed began to complain of a mysterious set of nagging ailments, including persistent fatigue, chronic headaches, joint pain, and nausea. The illness, for which the U.S. government continued to deny responsibility, became popularly named "Gulf War sickness."[12]

The Khamisiyah episode represented a giant blunder by the U.S. military. The huge desert complex of bunkers, measuring about the size of 100 Wal-Mart superstores, was known to be packed with "low grade" chemical and biological agents, including lethal agricultural pesticides, all of which were clearly marked. Yet nearby troops were not warned that the Army was about to detonate the immensely dangerous munitions. Nor were the soldiers removed to a safer distance or placed in protective gear. Instead, American commanders needlessly subjected their own forces to deadly chemicals.[13]

More than 15 years after the Gulf War, the Department of Veterans Affairs acknowledged that at least one-quarter of the Gulf War veterans were voicing similar complaints about their mysterious neurological problems. Federal studies utilized extensive data sets, including Pentagon data on potential exposure levels faced by the troops and magnetic resonance imaging to scan the brains of military personnel in the exposure zone. The emerging conclusion has been that the troops suffered injuries from several sources, including their exposure to nerve agents, oil-related pollutants, and many other hazards, such as pesticides, depleted uranium, and vaccines, to name a few. The soldiers also took pyridostigmine bromide (PB) tablets as a protection measure against nerve agent exposure. According to the government's report: "The strongest and most consistent evidence from Gulf War epidemiologic studies indicates that use of pyridostigmine bromide (PB) pills and pesticides are significant risk factors for Gulf War illness."[14]

Ten years after Halabja was attacked, writer Christopher Hitchens noted that Halabja's name "still wasn't very well known to most of the world." But he added, "Among Kurds everywhere it is like saying 'Guernica' or 'Wounded Knee' or 'My Lai.' " But 20 years after the attack, the chemical assault at Halabja was often cited as one of the worst war crimes of the era.[15] Historians generally agree that the incident initially claimed 5,000–7,000 lives, mostly helpless civilians, and caused tens of thousands of injuries. Observers acknowledge that many more deaths and countless more ill health effects have continued to surface over time, making Halabja the greatest chemical warfare attack on a civilian population in history. As one British physician who treated some of the Halabja victims explained, the Iraqis had dropped bombs containing a "cocktail" of deadly agents, including mustard, sarin, tabun, VX—"clearly intended to complicate the task of treating the Halabja victims."[16]

The transformation of Halabja's notoriety was primarily due to changes in U.S. propaganda efforts surrounding the second Iraq War. On August 26, 2002, Vice President Dick Cheney told the Veterans of Foreign Wars assembled in Nashville that Iraq possessed weapons of mass destruction that posed a clear and present danger to the United States. Containment may have worked during the Cold War, he said, but it was "not possible when dictators obtain weapons of mass destruction and are prepared to share them with terrorists who intend to inflict catastrophic casualties on the United States . . . the Iraqi regime has in fact been very busy enhancing its capabilities in the field of chemical and biological agents, and they continue to pursue the nuclear program they began so many years ago . . . There is no doubt that he is amassing them to use against our friends, against our allies, and against us."[17]

In the run-up to his invasion of Iraq, President George W. Bush said Saddam Hussein possessed chemical and biological weapons and was on the way to getting nuclear weapons, any or all of which he might share with terrorists threatening the United States. Bush said Halabja "provided a glimpse of the crimes Saddam Hussein is willing to commit." "The Iraqi dictator," he said, "must not be permitted to threaten America and the world with horrible poisons and diseases and gases and atomic weapons." He warned that America could not afford to wait until more evidence was presented. "America must not ignore the threat gathering against us," he said. "Facing clear evidence of peril, we cannot wait for the final proof, the smoking gun that could come in the form of a mushroom cloud."[18]

In February 2003, Secretary of State Colin Powell went before the United Nations and publicly laid out the U.S. case for war, claiming that his assertions were based on "solid sources . . . solid intelligence." "We have first-hand descriptions of biological weapons factories on wheels and on rails," Powell insisted. "Our conservative estimate is that Iraq today has a stockpile of between 100–500 tons of chemical weapon agents . . . He remains determined to acquire nuclear weapons."[19]

But the assertions made by Cheney, Bush and Powell turned out to be overstated, misleading, and incorrect. They also ignored the crucial role the United States and other Western nations had played in helping to build and monitor the Iraqi chemical weapons program over the years before the first Gulf War.[20]

In a propaganda effort just before the threatened U.S. attack, Iraq submitted a secret 11,000-page report to the UN Security Council listing 150 foreign companies from Germany, France, the United States, Britain, Switzerland, Netherlands, Italy, and China, which it said had supported Saddam Hussein's weapons of mass destruction program, according to a December 2002 news report in the Berlin newspaper *Die Tageszeitung* and innumerable reports in U.S. alternative news outlets. Iraq claimed that 80 German firms and 24 U.S. companies had supplied its weapons programs from 1975 onwards. The list contained several well-known multinationals as well as several front companies operating out of abandoned warehouses.† A few notable U.S. entries included the following:

†The U.S. companies and multinationals with U.S. affiliates included: "AT&T; Al Haddad Enterprises, Inc.; Alcolac International; American Type Culture Collection; Associated Instruments Distributors, Inc.; Axel Electronics; Banca Nazionale del Lavoro; Bechtel Group; Breezevale, Inc.; Canberra Industries; Carl Schenck AG; Carl Zeiss; Caterpillar, Inc.; Comtec International, Inc.; Consarc; Copeland International, Inc.; Data General Corp.; Dektor Counterintelligence & Security, Inc.; Dow Chemical; Dresser Construction & Equipment; Dupont; EG & G Princeton Applied Research; Eastman Kodak Co.; Electronics Associates, Inc.; Entrade International, Ltd.; Evapco; Finnigan Mat US; Foxboro Co.; Gerber Systems Technology; Gorman-Rupp; Hardinge Brothers; Hewlett-Packard; Hipotronics; Honeywell; Hughes Helicopter; IBM; International Imaging Systems; International Signal & Control; Ionics; Kennemetal, Inc.; Leybold Vacuum Systems; Lincoln Electric Co.; Litton Industries; Lummus Crest, Inc.; MBB Helicopter Corp.; Mack Trucks, Inc.; Maho AG; Matrix Churchill Corp.; McNeil Akron, Inc.; Memphis International, Inc.; Miller Electric; Mouse Master; NCR Corp.; NRM Corp.; Norwalk Co.; NU Kraft Mercantile Corp.; Perkin-Elmer Corp.; Phillips Export; Posi Seal, Inc.; Presray Corp.; Pure Aire; Redlake Imaging Corp.; Rexon Technology Corp.; Rockwell International Corp.; Rotec Industries, Inc.; Sackman Associates; Scientific Atlanta; Scientific Design Co., Inc.; Semetex; Servaas, Inc.; Siemens Corp.; SIP Corp.; Spectral Data Corp.; Spectra Physics; Sperry Corp.; Sullaire Corp.; Swissco Management Group, Inc.; Technical Communications Corp.; Tektronix; Teledyne Wah Chang; Thermo Jarrell Ash Corp.; TI Coating; Trading & Investment Corp.; Union Carbide; Unisys Corp.; Veeco Instruments, Inc.; Wild Magnavox Satellite; Wiltron; XYZ Options, Inc.; York International Corp.; and Zeta Laboratories." The list is cited in Jim Crogan, "Made in the USA: A Guide to Iraq's Weapons of Mass Destruction-Part II," *LA Weekly*, April 25–May 1, 2003.

- Phillips Export (then part of Phillips Petroleum, later Conoco Phillips) of Houston sold Iraq more than 500 tons of thiodiglycol, a material used to make mustard gas. Phillips Export/ConocoPhillips later was named as a defendant in a Texas civil suit filed on behalf of some 3,500 Gulf War vets who said they were suffering from Gulf War Syndrome.
- Union Carbide (later Dow Chemical) of Danbury, CT, shipped xylene for Iraq's chemical warfare program.
- Alcolac International supplied its mustard-gas ingredient to Iraq and Iran. In 1988 the U.S. Justice Department indicted the company for its illegal exports to Iran, via a German company, Chemco, and in 1989, Alcolac pleaded guilty to one count of violating U.S. export laws.[21]

The German firm Karl Kobe was said to have helped to build Iraqi chemical weapons facilities that were disguised as a pesticide plant. Other German firms allegedly sent more than 1,000 tons of precursors for chemical warfare agents. Britain supposedly helped build a chlorine factory that was used to make mustard gas. Brazil sold 100 tons of mustard gas. In short, war profiteers made a fortune by helping Iraq amass its weapons of mass destruction, and some of their host countries later used the claim that those weapons still existed to justify the "preemptive strike" against Iraq.[22]

According to a report by the U.S. Senate's committee on banking, housing and urban affairs, which oversees American exports policy, the United States under the administrations of Presidents Reagan and George H. W. Bush sold materials including VX nerve agents and "dual-use" licensed materials "which assisted in the development of Iraqi chemical, biological and missile-system programs." Senator Donald Riegle (D-Mich.), then chairman of the committee, said that between January 1985 and August 1990, the "Executive branch of our government approved 771 different export licenses for sale of dual-use technology to Iraq." He added, "I think that is a devastating record."[23]

Iraq's chemical warfare crimes were the subject of forensic investigations and prosecutions, but their scope was contained at the behest of the United States and other Western nations. Although Chemical Ali was sentenced to be hanged at Halabja, the world media devoted little effort to probing into the sordid details behind Iraq's infamous chemical warfare program.[24] The main question raised by the G. W. Bush administration, and parroted by the corporate media, was, "Where are Saddam's WMD's?"—not "How did Iraq become armed with chemical weapons in the first place?" or "Why had the 'civilized world' not condemned their use at the time, instead of waiting so long?" Questions of corporate complicity in chemical warfare were also avoided.

Chapter 14

Terrorist Attacks and Threats

From a subjugated place they produce gas and plague;
The times are changing. It is evening. Death from the Big Third.
—Nostradamus (sixteenth century)

SARIN (GB, GB2)

Tokyo

Shortly after the Cold War ended, a new worry arrived in the form of terrorist chemical attacks. It originated from a little-known religious cult in one of the world's most orderly and law-abiding nations: Japan. The source was a chubby, half-blind yoga instructor with flowing hair, who wanted to destroy the world in order to save it, and he had somehow enlisted some of Japan's most brilliant young minds in that apocalyptic mission.

Chizuo Matsumoto had been born in 1955 to an impoverished family on a tiny island in southern Japan. Born blind in one eye and only partly sighted in the other, he had grown up with little formal education and never would have ranked high on anyone's list of most-likely-to-succeed. But Matsumoto was not lacking in ambition or charisma, and his marriage to a wealthy woman enabled him to open an alternative health clinic in Tokyo that attracted a zealous, highly intelligent clientele. In 1987 after making a pilgrimage to the Himalayas to seek enlightenment, he began to introduce a radical new philosophy he had patched together from a crazy-quilt pastiche taken from Tibetan Buddhist meditation, Hinduism, the Book of Revelations, doomsday prophesies of the sixteenth-century French seer Nostradamus, pseudo science and the occult. Changing his name to Shōkō Asahara, meaning bright light connection, he set himself up as guru, the "one and only person who has acquired supreme truth," and claimed to possess unique powers, including levitation and telepathy.

Asahara said he identified with Shiva, the Hindu god of chaos and destroyer of the universe. One of his core beliefs was that the world was doomed, and only his most ardent disciples would be saved in the final battle, provided they renounced all previous connections and surrendered themselves to his will. Ashara required his followers to push their minds and bodies to the limit and beyond, undergoing hyper-rigorous physical tests that he claimed would heighten their transcendent experience. He made them take the Tibetan emphasis on the breath to absolute extremes, through extended submersion in water tanks and self-asphyxiation. To enforce absolute compliance, he employed beatings, rape, electric shock, LSD and other mind-altering drugs, and mind control. He also instituted a system he claimed would transfer his brain waves to each disciple through an electrical device known as the "perfect salvation initiation" (PSI), in order to create clones of himself. Using such methods, Asahara spread his apocalyptic message throughout Japan and beyond.[1]

Within a few years, he had established a headquarters of the cult, now called Aum Shinrikyō (teaching the Supreme Truth), in a quiet dairy farming area of the Mount Fuji foothills. He and his followers supplemented their legitimate income by organizing extortion, kidnapping, insurance fraud, and drug dealing. In 1989, Tsutsumi Sakamoto, a young lawyer representing several families who accused the sect of taking their children from them, mysteriously disappeared along with his wife and two-year-old child. An Aum Shinrikyō badge was later found on the floor of the victim's home, but the sect denied any involvement. (Six years later it was proved they had been murdered.) The cult's henchmen committed other murders as well.[2]

Asahara amassed holdings worth several hundred million dollars and formed his own political organization known as *Shinrito* or the Supreme Truth Party. When these efforts failed to produce the desired results, he began to hatch plots to overthrow the Japanese state and created his own secret government complete with twenty-two departments or "ministries," headed by brilliant and idealistic young lieutenants whom he had handpicked from top universities and corporations. Most were recruited when they were in their late twenties or early thirties. Convinced that the apocalypse was coming, Aum members were indoctrinated to believe they could only survive through combat, by becoming "superhuman." Their spiritual practice was designed to make them able to withstand bacterial, chemical, and nuclear attack. Scientists and physicians played key roles in helping Aum Shinrikyō prepare for Armageddon. Some of its agents met secretly with rogue scientists and corrupt arms suppliers from the former Soviet Union, seeking to obtain some of the tools that would enable them to start World War III. On one of these missions, they paid $100,000 to purchase blueprints for a state-of-the-art facility to produce sarin—a deadly nerve agent invented by the Nazis that could only be used as a chemical weapon—figuring that they could readily acquire enough chemicals to manufacture the poison on a very large scale. Shiva would be pleased.[3]

Sarin had originated with the Nazis, but even Hitler had not allowed his generals to use it. (See Chapter 9.) Just a few years earlier, Iraq's Saddam Hussein had broken the taboo by unleashing it on Iranians and Kurds.

Like tabun and soman, sarin was classified as a nerve agent because it attacks the nervous system. Over the years scientists had figured out more about how it works. According to the Centers for Disease Control, sarin, like other organophosphate nerve agents, inhibits the breakdown of the enzyme acetylcholinesterase so as to interfere with the body's nervous system. Soon after exposure, a victim may experience a runny nose, tightness in the chest and constriction of the pupils. Then he or she has difficulty breathing and feels nauseous. The person starts to lose some control over various body functions and may drool, vomit, defecate and urinate. There may be violent twitching and jerking. Eventually the spasms may cause the victim to become comatose. Death occurs by asphyxiation.[4]

By the early 1990s sarin had acquired the reputation as the "poor man's atomic bomb," which could not only kill any living creature with amazing efficiency but also leave the enemy's buildings or military hardware totally intact, and therefore available for reclamation. In 1992, the United Nations classified it as a "weapon of mass destruction," and the Chemical Weapons Convention of 1993 outlawed its production and stockpiling.

While scouting possible weapons of mass destruction to develop for themselves, Aum's scientists discovered they could readily acquire the chemicals needed to make sarin, and their contacts in the former Soviet Union taught them how to turn out large quantities on an assembly line. To secretly manufacture a huge supply of the poison, the cult constructed a mysterious holy place inside their Mount Fuji center. Named Satyam 7, after the Sanskrit word for "truth," the three-story windowless facility was placed under heavy guard and designated as a shrine reserved only for the most enlightened monks who had earned special security clearance.

In fact, Satyam 7 secretly housed a multi-million-dollar, state-of-the-art chemical and microbiology laboratory compound full of massive storage tanks and manufacturing equipment capable of producing vast quantities of deadly nerve agents. A pinhead-sized drop of sarin can kill a human being, and Asahara intended to make and use tons of it, establishing secret weapons research plants at several locations.

Inside the Satyam 7 cocoon, cult chemists labored around the clock to synthesize VX, mustard gas, and other lethal chemicals. Biomedical technicians in white coats used the most advanced techniques available to culture agents that would cause anthrax and other horrid diseases. Assembly line workers churned out large stocks of machine guns and tons of TNT. The cult leaders were preparing for the end.

But making the weapons was only part of the challenge they faced. They also had to learn how to use them effectively. This did not prove easy. In the early 1990s, members of the cult made several failed attempts to release botulin toxin and anthrax spores at various targets in Tokyo, without getting caught, and a few years later they dispatched a team to Central Africa in an effort to acquire the Ebola virus. They also sent representatives to the United States for helicopter pilot training. Aum claimed to have 10,000 followers across the globe, with the greatest number in Russia, and said their army was growing.

Sarin proved particularly difficult to control. Building an arsenal of good-quality sarin was no easy task. The liquid can degrade in just a few weeks, making for a relatively short shelf life, and its potency can also vary considerably, depending upon the impurities in its precursor chemicals; its storage and handling are also extremely hazardous. Several Aum technicians suffered permanent injuries while trying to make the poisons. Neighbors around the Mount Fuji plant complained to the police about foul odors and sick livestock, but the authorities failed to investigate.

Aum chemists also took some of their sarin to Australia for field tests. They successfully killed dozens of sheep tethered to poles, making their initial efforts with the nerve agent appear quite promising. While in Australia they also tried unsuccessfully to obtain uranium for use in nuclear weapons.

By early 1994, the sect's chemists had synthesized 44 pounds of sarin, and Ashahara ordered them to begin mass production, calculated at two tons per day, until they had stockpiled at least 70 tons to unleash against targets in Japan and the United States. The quantities were mind-boggling, but first he wanted to refine their killing techniques.

In April 1994, an Aum hit team tried to murder a rival religious leader using sarin, but their spraying device malfunctioned and instead released some of the agent on their own security chief, Tomomitsu Niimi, who would have died had one of his confederates not administered the antidote just in time. Once again, the attackers managed to avoid getting caught.[5]

Having evaded prosecution for so long, Aum's leaders came to see themselves as invincible and the Japanese government as hapless. Writing at the time without specifically referring to the cult, Kensaburō Ōe, Japan's Nobel Prize winning novelist, described his country as "split between two opposite poles of ambiguity" — a trait that the American psychiatrist and writer Robert Jay Lifton later interpreted as a "particularly troubled version of psycho-historical dislocation" that he said contributed to the "ethical 'invisibility' within Japanese society . . . [that was] undoubtedly a factor in the Aum phenomenon."[6]

In June 1994, the Aum Shinrikyō planned its first large-scale assault using sarin. Their target was in the city of Matsumoto, outside Tokyo, where local judges were preparing to issue a ruling against the cult in a land dispute. Asahara ordered the judges assassinated, and he also wanted to learn how sarin would work in a heavily populated area. The attackers waited until the weather reached optimum conditions. Commandoes from the sect drove a specially converted refrigerator truck into the residential neighborhood where the judges lived and used computers and electric fans to blow a cloud of sarin at the apartment complex. But everything did not go according to plan, and the vehicle became endangered. After 20 minutes of gassing, the attackers panicked and fled, leaving the gas cloud to seep into open windows and get picked up by cross breezes. Residents in their apartments began to experience terrible headaches, dizziness, shortness of breath, and cramping. Victims expelled bloody vomit. Some went into convulsions and fell into a coma. After the vapors subsided, five residents were dead (two others died later), and 300 more were rushed to local hospitals, where befuddled physicians detected extremely low levels of cholinesterase and treated their patients for organophosphate poisoning from some unknown source.

Fortunately for the Aum attackers, the government's perplexed crime scene investigators noticed dead caterpillars and shriveled vegetation, which led them to suspect erroneously that one of the first victims had been trying to manufacture some kind of homemade herbicide and it had gotten out of hand. The victim became the prime suspect. The police and news media pestered the man to confess, until the results of laboratory forensic analysis indicated that sarin traces had been found in the vicinity where eyewitnesses reported having seen a mysterious van releasing a whitish vapor.[7] Once again, Aum's attackers evaded detection. And injuries to the judges forced the court to suspend its proceedings against the sect, thereby crowning the mission with success. Back at their headquarters, the cult members celebrated their triumph by singing a song that acknowledged their debt to Nazi Germany.

As law enforcement agents looked more closely into the sect's involvement with deadly chemicals, Asahara ordered his security chief to crack down on any possible informers. The cult used everything from kidnapping and truth serum to torture and murder to root out confessions. It also went to extremes to destroy evidence: in one instance, the corpse of one of their victims was cooked for two days in a large industrial microwave oven, and then the remains were soaked in a bath of nitric acid. Aum's operatives also prepared a list of targets marked for assassination. One hit team surprised their prey by squirting lethal VX nerve agent onto his neck—a homicide the police were unable to solve.[8]

Knowing that his headquarters was about to be raided, Asahara had his followers hide or destroy anything that might incriminate him. They carted away batches of sarin and buried them at secret locations, dumped large stocks of toxic chemicals into a well, and shredded or burned heaps of documents. When the "cleanup" was complete, Asahara invited a delegation of journalists in to inspect Satyam 7. All they found was a shrine containing a 15-foot-high Styrofoam Buddha, classrooms and a storage area. Cult propagandists then went on the offensive, charging that the Japanese government was plotting to attack them with nerve gas.

At the same time, Asahara secretly ordered his top lieutenants to mount a major sarin attack miles away in Tokyo, hoping it would divert attention from them. He set the date for only two days away, giving his scientists scant opportunity to mix an adequate supply and formulate their attack plan. The tight time frame forced them to produce a strain of sarin that was only 20-30 percent pure, but they had no choice. Wearing gas masks and other protection, the chemists injected 20 ounces of the sarin solution into 11 empty plastic bags made of sturdy nylon-polyethylene. To prevent leakage, each bag of sarin was heated inside another larger plastic bag and each was placed inside a wrapper of folded newspaper.

Hideo Murai, the Science and Technology minister, came up with the idea of organizing a series of coordinated sarin attacks on five subway trains traveling on three different lines, so that they would converge at Tokyo's busy Kasumigaseki station during the early-morning rush hour. Tokyo is the world's largest city with the most heavily traveled subway system, and Kasumigaseki serves the buildings housing most key agencies of the Japanese government, so the simultaneous strikes were designed to foment maximum terror and attack the state at its core.

On the morning of March 20, 1995, a team of nervous Aum agents boarded the five different trains and waited until they received their signal. The attackers had carried out a practice run using plastic bags filled with water, and that test had gone off rather smoothly. But unleashing real sarin in an enclosed subway car against actual live human beings was more challenging. At the precise moment that had been set, each agent was supposed to remove two or three innocuous-looking newspaper packages from his backpack and deposit the objects on the car floor. Just before the subway door closed, each agent attempted to pierce each plastic bag with a sharpened umbrella tip before quickly exiting the car, while reciting his mantra as he made a quick escape from the subway platform.

By and large the team did what they were told: although they had failed to pierce a few of the bags, each team member had more or less performed his mission. One by one, they threw their contaminated umbrellas into the river, changed clothes, and burned their work clothes before racing back to their hide-out. Some felt sick and had to be injected with atropine and PAM.

Meanwhile, back in the subway cars, eight of the 11 bags were spilling a strange brown liquid over the floor. As the substance evaporated, a deadly vaporous sarin agent spread throughout the cars and out the open doors onto the surrounding subway stations. Some passengers began to detect an odd smell, which gave them a sensation of being suffocated. Soon they began to cough, choke, and wheeze. Passengers began dropping their briefcases and purses and covering their mouths. A few clutched handkerchiefs to their faces. Some saw others' eye pupils contracting. Passengers were struggling to exit the car and flee along the platform, but some began collapsing and twitching uncontrollably.

Nine minutes after the first release, Tokyo police received their first garbled report of an explosion inside the subway system: they were told to expect numerous casualties from burns and gas, probably carbon monoxide. Ambulances and rescue personnel rushed over to find terrified commuters staggering from 15 underground stations, and sprawled on the sidewalks. Some rescuers began aiding the stricken passengers, while others continued below to the affected platforms and cars. Not being equipped with gas masks or other protective gear, some responders also collapsed. The others came upon a scene of horror. At Kamiyacho station, 50 victims lay thrashing on the platform, vomiting, foaming at the mouth, bleeding from the nose, or convulsing. In the confusion, the trains had not yet been stopped. Television crews were descending from every direction.

The attack left 12 people dead and as many as 3,800 injured. Fifteen of the world's busiest subway trains and stations were contaminated. Images of stricken and panicked passengers flashed across the globe, igniting a firestorm of terror in Tokyo, London, New York and other major cities. Hospitals reported that some victims had sustained irreversible brain damage and other permanent injury. But the attacks failed to immobilize Japan's government, cause thousands of deaths, or trigger Armageddon. Media coverage of the victims was minimized, and in keeping with the Japanese psyche, many of those who had been injured actually seemed to be avoided and even stigmatized, as public attention focused on the perpetrators, whoever they might be. Residue of acetontrile—a solvent that can be used to produce sarin—had been found in the damaged Tokyo subway and the police began to uncover other evidence pointing to the deadly nerve agent.

It did not take long for Aum Shinrikyō to become a prime suspect. Within 48 hours of the subway attack, police in gas masks and protective suits commenced raids against Aum facilities throughout Japan. The search of some sites uncovered about two tons of chemicals, including 15 or more bottles of acetontrile. The police also found other sarin precursors as well as sodium cyanide, another deadly poison. The police forensic team discovered ethyl alcohol, which they said could be used in making yet another kind of nerve gas. They also found gas masks and other chemical warfare paraphernalia, and came across a dazed woman in a crate who said she had been confined there under sedation for saying she wished to leave the cult.[9]

Somebody came across a tape from a Russian radio program in which Asahara warned that "the time for awakening" and "the time for death" had arrived and his followers should be ready to die. There was also literature forecasting that gas attacks and other calamities would soon kill 90 percent of the people living in major cities, culminating by 1997 in the end of the world. The more the police dug, the more they found. In one raid, investigators uncovered more than 50 sect members in the group's "chapel," lying on the floor, apparently very weak from malnutrition and dehydration. But the sect's leadership remained in hiding.[10]

Another search of a cult compound in Kofu turned up a staggering 500 drums of phosphorus trichloride, as well as other chemicals necessary to manufacture one of the most lethal agents known to man. Government officials were embarrassed to admit that the sect apparently did not break any laws by buying and storing the deadly chemicals, since under Japanese law it was not even illegal to make or possess sarin itself, simply because lawmakers had never considered the possibility. The public was shocked, and other governments throughout the world scrambled to see if they too were vulnerable.[11]

Wire service reports from Japan particularly shocked American intelligence officials, who had known nothing about Aum Shinrikyō or Asahara until they saw details on the world news on Sunday evening, March 19. Richard A. Clarke, the terrorism advisor for President Bill Clinton, immediately initiated calls for law enforcement and scientific assessments, and an urgent meeting was held the next day in the White House situation room to bring together officials from the CIA, FBI, State Department, the Pentagon, and other agencies. Soon it became clear that the cult had an office in New York at 8 East 48th Street, just a short walk from one of America's busiest subway stations. FBI agents and New York police jumped on the group, putting them under surveillance, but nothing materialized.[12]

The aftermath of the subway attack continued to yield one astonishing development after another. More than a month after the first raids, further searches uncovered seven members of the cult hiding in secret underground compartments beneath their headquarters.[13]

Amid the rising international furor over the sect's activities, on April 23, Hideo Murai, the sect's Minister of Science and Technology, was being filmed live by a battery of television cameras as he attempted to enter the sect's Tokyo office, when a man suddenly lunged forward with a seven-inch kitchen knife. The cameras continued to capture the scene as the attacker quickly slashed the victim's left wrist, and then repeatedly thrust and twisted the blade deep inside Murai's abdomen, killing him. The confessed attacker, Hiroyuki Jo, a 29-year-old Korean, and some accomplices denied any links to Aum Shinrikyō and were later identified as contract killers for organized crime, but most observers believed that Asahara had ordered the killing to keep Murai from talking.[14]

Conspiracy theories abounded, particularly after it was revealed that Murai's role within Aum Shinrikyō was to develop the most sophisticated types of weapons of mass destruction, some of which had never been revealed outside of James Bond movies. One plot featured using an advanced laser-powered seismic device that supposedly could trigger massive earthquakes such as the one in central Japan on January 17, 1995, that had killed more than 5,500 people. Murai further electrified reporters by saying, "There is a strong possibility that the Kobe earthquake was activated by electromagnetic power or some other device that exerts energy into the ground." He also claimed to have been exploring the use of "death rays" and other high-tech weapons of mass murder.[15]

Asahara, Endō, and hundreds of other leaders of Aum Shinrikyō were rounded up and charged with various crimes. The Tokyo subway attack launched new global concerns about terrorist use of chemical weapons and other vehicles of mass destruction. It inspired the development of new technologies to detect dangerous chemical and biological agents and treat victims of attacks caused by these agents. Subsequent testing determined that impurities in the hastily manufactured sarin used in the Tokyo attacks fortunately resulted in far fewer casualties than otherwise might have occurred. Had it been more than 20 percent pure, the impact would have been much worse.[16]

Based in part on the Japanese experience, the 1993 World Trade Center bombing, the devastating attack on the Oklahoma City federal building, and other post-Cold War terrorist threats, on June 21, 1995, President Clinton signed a secret directive on counter terrorism that stated: "The United States shall give highest priority to developing effective capabilities to detect, prevent, defeat and manage the consequences of a nuclear, biological, or chemical materials or weapons use by terrorists."[17]

By 2004, after an eight-year-long trial, Shōkō Asahara and 11 others were convicted and sentenced to death by hanging. Dozens more were convicted of lesser charges and sentenced to long prison terms. In the wake of the attack, the Aum Shinrikyō renounced many of its former practices and changed its name to Aleph. In 2004 it boasted more members than it had in 1995.[18]

Chlorine, Hydrogen Cyanide, Sarin, VX, Sulfur Dioxide

Al Qaeda's Chemical Bombs

The Aum sect was not the only terrorist organization to use chemical weapons. On January 28, 2007, insurgents fighting in Iraq began to resort to chemical warfare using makeshift chlorine-gas bombs. A 150-pound cylinder of pressurized chlorine gas would be positioned in a dump truck or pickup and set off by an IED (improvised explosive device) that would expel poison gas as well as shrapnel. Chlorine was widely available, due to its legitimate use in water purification, and fashioning a chemical bomb did not require tremendous know-how. But it could spread considerable fear.

The first attack occurred in Ramadi, when terrorists detonated small quantities of explosives in several trucks containing liquid chlorine, killing 16 people and wounding several dozen more. Then, on back-to-back days in February, two trucks carrying chlorine gas canisters were exploded at different locations, killing at least five persons and seriously injuring more than 205 civilians. After the blasts, U.S. and Iraqi forces quickly raided two chlorine factories in Karma and Fallujah in al Anbar province, discovering a total of four vehicles that were being made into chlorine car bombs.[19]

A few weeks later, another coordinated gas attack occurred when bombers detonated three chlorine-filled trucks in al Anbar, killing 8 persons and severely injuring over 500 others. The bombs went off at a checkpoint north of Ramadi, and at two locations just south of Fallujah. Besides inflicting serious casualties and delaying rescue efforts, the gas wrought terror among the mostly Sunni population. Police noted that suspected al Qaeda suicide car bombers had used chlorine bombs in al Anbar five times in the past two months, indicating that it had become a pattern.[20]

Three weeks later at Ramadi another suicide bomber exploded a large truck laden with chlorine, killing 30 people and injuring nearly 100. The attacker struck in late morning on the Muslim day of prayer—a time when many people were congregating in the street. This time it was no small truck; the terrorists had used a fuel tanker loaded with chlorine.

The bombings signified alarming new dangers in the Iraqi occupation, but they were not the first time that al Qaeda had tried to use chlorine or other toxic chemicals as weapons of mass destruction. In the first attack on the World Trade Center on February 26, 1993, the terrorists detonated a 1,500-pound urea-nitrate bomb in the parking garage below 2 WTC, hoping to cause it to collapse onto its twin. But amazingly, the tower withstood the blast and only six persons were killed, but over 1,000 were injured.

Unfortunately for the terrorists, their handiwork left clues that enabled forensic investigators to eventually recover several pieces of key evidence. The trail ultimately helped them to determine that the mastermind, Ramzi Yousef, had planned to add sodium cyanide to the explosives, hoping to create additional havoc. But the cyanide was apparently destroyed in the explosion, so the poison had no effect. "We [have] the ability to make and use chemicals and poisonous gas," Yousef wrote a few months after the bombing. "And these gases and poisons are made from the simplest ingredients, which are available in the pharmacies; and we could, as well, smuggle them from one country to another as needed. And this is for use against vital institutions and residential populations and drinking water sources and others . . . "[21]

Police later arrested a terrorist cell based in Jersey City, New Jersey and after a worldwide manhunt, Yousef was finally caught in Pakistan in 1995. As a result, agents began to learn more about his links to al Qaeda, his ties to Osama bin Laden, and the fact that he had attended a terrorist training camp in Afghanistan, where he had acquired expertise in explosives making and poisons. In June 1998, the U.S. government indicted bin Laden and members of al Qaeda for engaging in international terrorism. And the war with al Qaeda was underway.

Before the indictment was announced, in August 1998, the U.S. military compiled intelligence that the Al-Shifa Pharmaceutical Factory in northern Khartoum, Sudan was being used by Sudan and al Qaeda to make the VX nerve agent. The circumstantial evidence included soil samples from the area of the plant, showing traces of an organophosphate compound called EMPTA that informants said was to be used as an intermediary in the Iraqi process to make VX. Although the intelligence was flimsy, the Clinton administration launched 13 Tomahawk cruise missiles at the plant, killing a security guard and seriously wounding ten civilians. The validity of the missile attack was later challenged in the world media. But the United States was determined not to allow terrorists to build weapons of mass destruction.[22]

Bit by bit, more pieces of intelligence about bin Laden's chemical warfare intentions continued to accumulate. In February 2001, al Qaeda had planned to launch a nerve-gas attack on the European Parliament building in Strasbourg, France. The assault was timed to happen between February 11 and 14 when 625 Euro-MPs were scheduled to be in the building. The European Parliament was supposed to be the first in a string of similar attacks. The plot involved Algerian terrorists based in London, working with cells in Milan and Frankfurt, but German police broke up the plot. However, authorities held back on their crackdown in hopes of being able to eavesdrop on subsequent activities of the British-based cell.[23] This time the gas al Qaeda had chosen for use on the European Parliament was sarin.

Then American agents turned up clues about another apparent plot. In 2001 Ahmed Ressam, an Algerian who was imprisoned in the United States for his role in an aborted plot to bomb Los Angeles International Airport during the 2000 Millennium celebrations, confessed to having attended an al Qaeda training camp in Afghanistan in 1998. Ressam described taking part in cyanide experiments on dogs. He also said he and other trainees were taught how to introduce a small amount of the poison into an office building's air filtration system to kill a large number of people. Most worrisome of all: Ressam told interrogators that al Qaeda "sleeper cells" in the U.S. were preparing to mount some sort of major terrorist attack in the United States. This information found its way into the famous Presidential Daily Briefing of August 6, 2001, entitled, "Bin Laden Determined to Strike in U.S.," that was presented to President George W. Bush. But Bush did not respond.[24] Then the September 11 attacks occurred.

More disturbing clues about al Qaeda's chemical warfare activities surfaced shortly afterward, following the American counterattack on terrorist havens in Afghanistan. On October 12, 2001, American air strikes destroyed al Qaeda's Darunta training camp near Jalalabad in Afghanistan, one of the places where Ressam had received his chemical warfare training. The strikes left a pile of smouldering rubble for local tribesmen to sift through.

The camp had been run by the shadowy al Qaeda operative Midhat Mursi al-Sayid Umar aka Abu Khabab al-Masri, whom intelligence agents believed was the red-bearded *jihadi* in charge of the group's biological and chemical weapons program. A former Egyptian military specialist in chemical warfare, Masri had reportedly graduated from Alexandria University and later joined Dr. Ayman al-Zawahiri's Egyptian Islamic Jihad, where he served as an explosives expert and poison trainer. A top lieutenant of Osama bin Laden, he moved to Saudi Arabia in 1987 and Afghanistan in the 1990s. Masri apparently set up the first al Qaeda chemical weapons laboratory in 1999, moving the lab's location every three months in an effort to evade his pursuers. At the Darunta headquarters, Masri had provided hundreds of *mujahidin* (Muslim guerilla fighters) including Ressan, the "shoe bomber" Richard Reid, and "dirty-bomber" Zacarias Moussaoui, with hands-on training in chemical warfare using makeshift weapons. Hours before American missiles struck the Darunta camp, the elusive terrorist somehow managed to escape and head for the Pakistan borderlands.[25]

But Masri left much behind in the bombed-out wreckage: bottles of poison, gas masks, gas detector papers, and a library of English-language instruction manuals on chemicals, bomb-making and guerrilla warfare, which were later recovered. Looters sold one of the camp's desktop computers to a *Wall Street Journal* reporter for $1,100, and it yielded a treasure trove: records of international money transfers, formulas for making sarin, and other revealing evidence. Some of the text files outlined an al Qaeda project that was code-named *al-Zabadi* (Arabic for curdled milk). Its purpose was to develop chemical and biological weapons using readily available materials.[26]

From a black market dealer, the CNN correspondent Nic Robertson obtained 64 videotapes (a quarter of the complete library) showing precise instructions about how to use sarin chemical weapons. The chilling video footage featured staged experiments with three dogs being gassed to death with some sort of poison, such as Ressan had previously described. Analysts said the animals' reactions made them think it involved a nerve agent such as sarin. The evidence salvaged from Darunta graphically demonstrated al Qaeda's sinister intentions regarding chemical and biological weapons. Based on what turned up, the U.S. posted a $5 million reward for Masri's capture.

In January 2006, Masri was again in the news when intelligence officials said he was among those killed in a Predator missile strike in Eastern Pakistan. However, security officials later determined he had not been in the village at the time and claims of his death became suspect.[27] In February 2007, American forces south of Baghdad captured a top aide to Masri, but the bomb maker eluded them again.[28]

In late July 2008, international news services again reported Masri's death. This time, it was claimed he had been struck by a U.S. Predator missile in South Waziristan, Pakistan. Al Qaeda later issued a press release confirming his death, but some intelligence experts remained wary.[29]

American intelligence agents stumbled upon one of their most stunning discoveries in 2003, when they belatedly found that al Qaeda terrorists had come close to attacking the New York subway system with hydrogen cyanide gas delivered by a revolutionary new gas-dispersal device known as "the *mubtakkar*" (Arabic for inventive).

The first inklings of the plot arose when Saudi police captured a laptop computer belonging to a Bahraini *jihadist* and learned it contained plans for a newly invented tool that terrorists could use to distribute hydrogen-cyanide gas effectively to achieve mass casualties. Like other al Qaeda creations, the doomsday device could also be cheaply and easily constructed from generally available household materials sold at Home Depot, and it could be easily concealed. Immediately after obtaining the plans, the CIA built and tested a unit based on the prototype and found to their dismay that it worked remarkably well.

The next day, CIA officials showed the device to President Bush and Vice President Dick Cheney.

For some unknown reason, al Qaeda's second in command, Dr. Zawahiri, had called off the attack just 45 days before his agents were poised to place several *mubtakkars* in New York City subway cars and at other strategic locations. The United States had dodged another bullet. But al Qaeda still knew how to make their doomsday device.[30]

The United States was not their only target. On December 16, 2003, hundreds of French police raided the upscale Cité des 4000 housing complex outside Paris. They arrested a 29-year old French-Algerian, Marwan Ben-Ahmed (aka Merouane Benhamed), for possession of bomb-making materials. He had been caught loading two empty propane canisters with toxic chemicals for an attack on some political institution. (Just as al Qaeda had aimed to attack the European Parliament, two years earlier.) One of Ben-Ahmed's associates, Rabah Kadri (another Algerian), had been arrested on November 5, 2002, for planning a chemical attack on the London Underground. The pair was belonged to al Qaeda's "Frankfurt group."[31] Now more information about the chemical conspiracies was coming to light.

The police continued to crack more cases. On March 30, 2004, British agents arrested six members of the Islamist group Al Muhajiroun for conspiring to attack Gatwick Airport or the London Underground with the highly toxic chemical osmium tetroxide.[32]

One month later, in April 2004, Jordanian police seized 20 tons of chemical weaponry including sarin that was linked to a plot to attack the Jordanian Intelligence Services headquarters. If successful, the attack could have killed as many as 20,000 people.

A month after that, in May 2004, terrorists recorded their first attack using chemical-weapon IEDs in Iraq, when they detonated a roadside bomb made of a 152-mm artillery shell containing two precursors of sarin. Two soldiers who had handled some of the shrapnel were mildly affected. American forces later found hidden weapons caches with 12 similar artillery shells containing sarin and mustard gas. Clearly, the graduates of al Qaeda's explosives and poisons training camp were leaving their mark.[33]

In the United States, fears about another cataclysmic attack reached a fever pitch after the blows against New York and Washington. Within days of September 11, 2001, some security experts began expressing concerns that chemical plants constituted one of the ripest targets for further terrorist assaults against the United States. One early revelation concerned Mohamed Atta, the al Qaeda ringleader leader of the 9/11 attack, whom eyewitnesses identified as a stranger who had visited a small airport in Copperhill, Tennessee in March–April 2001. It appeared that Atta inquired into renting or buying an airplane and also showed unusual interest in a nearby chemical plant, wanting to know what kind of chemicals were stored there. (It turned out the plant's huge tanks held

250 tons of sulfur dioxide—a prime target, which, if exploded, probably would have inflicted a sizable death toll among the 60,000 local residents in that vicinity.)[34]

After 9/11, some officials became so concerned about terror threats that they substituted a safer chemical for the deadly chlorine gas used in their wastewater treatment, and hastened to take other precautions to protect toxic chemical plants and storage facilities. A Justice Department study acknowledged, "The ubiquitousness of industrial facilities possessing toxic chemicals and their proximity to population centers also make them attractive targets." But Bush administration officials and industry spokesmen tried to assure a worried public that the chemical industry was addressing the problem. "Certainly, the industry has a very powerful incentive to do the right thing," Bob Bostock, assistant EPA administrator for homeland security, told the *Washington Post*. "It ought to be their worst nightmare that their facility would be the target of a terrorist act because they did not meet their responsibility to the community." Nevertheless, a review of government documents obtained by the *Post* described dozens of dangerous conditions, including the following:

- A California chemical plant routinely loaded 90-ton railroad cars with enough chlorine to poison more than 4 million people in Orange and Los Angeles counties.
- A Philadelphia refinery held enough hydrogen fluoride to asphyxiate nearly 4 million nearby residents.
- A South Kearny, New Jersey chemical company's store of chlorine or sulfur dioxide was sufficient to threaten 12 million people.
- The West Virginia sister plant of the infamous Union Carbide Corp. factory in Bhopal, India, stored enough methyl isocyanate to endanger over 60,000 local residents.
- The Atofina Chemicals Inc. plant near Detroit acknowledged that a rupture of one of its 90-ton rail cars full of chlorine could endanger 3 million people.[35]

The EPA disclosures represented only the tip of an iceberg. In 2003, a local Internet blogger near Buffalo, New York began to report on security problems at the nearby VanDeMark Chemical Company manufacturing plant, located on one of Lockport's main thoroughfares, close to the city population center. It turned out that the company, which was owned by the French government, manufactured phosgene—one of the world's deadliest chemicals, and one of the gases most responsible for Union Carbide's deadly Bhopal catastrophe in India. The Lockport plant was America's sole merchant supplier of phosgene. A company spokesman said the plant shipped its poison phosgene gas all over the country under "high security," explaining that this meant it employed a fleet of three trucks that were manned with two drivers per truck, and equipped with

Global Positioning System technology—as if this was supposed to reassure the public. To make its product, the Lockport facility utilized two highly poisonous gases—chlorine (brought in by rail) and carbon monoxide (brought in by truck)—which it combined in a large reaction vessel with a catalyst to produce the phosgene. The phosgene was then stored in various sized tanks. After being allowed to tour the Lockport facility, a blogger noted seeing storage tanks that did not have any markings to indicate what chemical they contained; some one-ton storage tanks were also observed in unsheltered, unventilated areas. The blogger also learned that the plant had had several accidents in recent years, including a laboratory explosion, a chlorine leak, and a truck mishap involving an unlicensed and uninsured driver who crashed his vehicle containing carbon monoxide in the middle of town. Such reports did not inspire confidence. Four years after the blogger's visit, the French company sold VanDeMark to Buckingham Capital Partners, a New York-based holding company.[36]

But that situation was not the only safety problem facing the chemical industry in the aftermath of September 11. Jim Mackris, chief of the EPA's Chemical Emergency Preparedness and Prevention Office, acknowledged to the *Wall Street Journal* in 2004 there was still "quite a bit of work to do." Some EPA officials noted that the Bush administration had put more regulatory restraints on the EPA than on the companies themselves. In 2002 when the EPA's then-director, Christie Todd Whitman, tried to force the chemical industry to tighten security, White House officials nixed her plan. Three years after 9/11, chemical plants still were not subject to federal security controls.[37] By 2006, only 225 of 14,000 industrial plants in the country had switched to using less dangerous chemicals or were no longer handling large quantities of extremely hazardous substances.[38]

Most critics, such as Greenpeace, focused on chlorine plants. In 2007, Greenpeace noted that the U.S. Naval Research Laboratory had warned that a catastrophic release of a tank car of chlorine or similar chemical within blocks of Capitol Hill could kill or injure up to 100,000 people in the first 30 minutes. Six years after 9/11, the federal government still had done very little to address the chlorine problem. As the ninth highest volume chemical produced in the United States, chlorine remained so widely exempt from government regulation that many law enforcement and terrorism authorities called ever more urgently for more controls on its storage and sale.[39] Critics continued to question the Bush administration's hands-off policy toward the chemical industry.

In August 2007, CNN's Deborah Feyerick reported from an area of northern New Jersey she said the FBI called "the most dangerous two miles in America," due to its abundance of chlorine storage facilities. "The EPA publicly lists 100 facilities that threaten one million people or more," Feyerick said, "and yet six years after 9/11, the Department of Homeland Security (DHS) admits it has no clear idea how secure any of the nation's thousands of chemical plants really are." The news correspondent noted that new federal regulations actually *exempted* water treatment plants from federal oversight, even though they were among the biggest users of chlorine.[40]

But the Bush administration still appeared unmoved. By February 2008, the neglect remained so serious that the New York Police Department took the unusual step of offering a public demonstration. The NYPD revealed it had set up an undercover sting operation in 2007 to purchase large quantities of toxic chlorine—to see how easy it might be for terrorists to obtain the chemical. Undercover cops set up a fake water-purification company, simply using a credit card to buy 300 pounds of chlorine over the Internet. New York police videotaped all of their activities as part of "Operation Green Cloud," showing a truck delivering the chlorine to a Brooklyn neighborhood lined with warehouses. In the grainy surveillance version, the purchasers were actually undercover police.[41] But some day, New Yorkers might not be so lucky.

Chapter 15

Disposal and Control

Dumping

Starting after World War I and continuing for decades, a few victorious nations found themselves with more unwanted poison gas than they could handle. And just because many huge stocks of chemical weapons had not been used on the battlefield did not mean they were no longer deadly. In fact, over time many chemicals had become less stable, more susceptible to leaking and theft, and therefore more dangerous to whoever possessed them.

And what did the victors do with their lethal hot potato? Some of it they diverted into "constructive" industrial uses or incinerated. But, in the perceived interests of safety, much of it ended up elsewhere in the earth's ecosystem: it was simply dumped into oceans and seas.

In 1919, at the Ohio plant that had produced deadly lewisite gas, the U.S. Army placed more than 150 tons of the poison into 55-gallon drums and loaded them onto freight cars for transport to Baltimore, a harrowing rail journey of two full days through populated areas. Then soldiers carefully put the drums onto waiting barges. The military took them 50 miles out into the Atlantic where it was three miles deep and unceremoniously dumped all of the lewisite containers into the ocean. Many more stockpiles of chemical munitions met the same watery fate at scattered locations off the coast of North America and Europe. In those days, nobody gave it much thought.[1]

Decades later, during World War II and its aftermath, the Allied powers seized nearly 300,000 tons of chemical weapons from the Nazis alone. German workers had packed much of the liquid mustard in wicker baskets, on the theory that the branches would help absorb whatever leaked out of the bombshells. Later, however, when the victors dumped the tons of poison gas containers in the ocean, sometimes at shallow depths and close to shore, in straits or among commercial fishing areas, many of the wicker baskets simply floated to the surface, thereby spreading the poison over a wider area and making it more hazardous to passing maritime traffic.

The U.S. military especially resorted to massive ocean dumping to remove unwanted chemical weapons from its stockpile. Military officials seldom left any precise records about what was dumped where, nor did they later follow up to see what, if any, impact they had wrought. They simply assumed the vast, cold ocean was the safest place to discard it, thinking that the action of the seawater would eventually render the chemicals inert. The planners were seemingly oblivious to the damage it would cause to humans and marine life for generations to come.

From June 1946 to August 1948, the U.S. military launched Operation Davey Jones Locker, by which 30,000–40,000 tons of poison gas containers were dumped into Scandinavian waters. The Navy scuttled nine gas-laden ships in the Skagerrak Strait and two vessels in the North Sea, and also dumped another 46,000 tons of chemical weapons in the Baltic. Like the Americans, the Soviets as well discarded some of their munitions in wooden cases that continued to float and drift for long distances. In the late 1940s, the British sank 34 shiploads with 127,000 tons of chemical and conventional weapons in the Norwegian Trench, and dumped other hazardous loads at a site 20 miles west of Ireland. A few years later, in the mid-1950s, the British crammed three large merchant ships with cyanide, nerve agents, phosgene, and mustard, and sent them to the bottom off the Outer Hebrides and Northern Ireland, in an operation known as Operation Sandcastle. An iron curtain of national security covered all such dumping; local inhabitants or fishermen were never informed, and nobody checked to determine what damage had been caused.[2]

One of the biggest post-World War II dumps in American waters occurred off the coast of South Carolina. The first documented drop in that operation took place in March 1946, when the *SS Diamond Head*, an ammunition ship, transported four railroad cars stuffed with mustard gas bombs and mines to a spot designated Disposal Site Baker, and unceremoniously lowered them into the ocean. Several months later, 23 barges, each carrying up to 350 tons of German-made nerve-gas bombs and U.S.-made lewisite bombs, were sunk nearby. Two years later the Army carried out Operation Geranium, dumping another 3,150 tons of lewisite off Charleston in the scuttled ship, *SS Joshua Alexander*. More than half a century later, marine biologists still have not determined where all such dumping was done or what its effects were or still might be.[3]

Many more large dumps of poison gases occurred during the Cold War. After the end of the Korean conflict, the military ordered the mass destruction of "obsolete" lewisite from U.S. stockpiles and called for its "burial in deep water." In 1957, the Army sank 48 tons of lewisite into the Atlantic off Virginia Beach, at a depth of 12,600 feet. Four more dump zones were created more than 100 miles off the coast between such popular unsullied tourist beaches as Chincoteague, Virginia, and Assateague, Maryland. The zones became a deadly trash bin for 77,000 mustard-filled mortar shells, 5,000 white phosphorous munitions, and 1,500 tons of lewisite, all of which was dropped to a shockingly shallow depth of about 2,000 feet. The Army also threw in 800 55-gallon steel barrels of radioactive waste, some of which had a half-life of thousands of years.[4]

In the spring of 1959 the *SS William C. Ralston*, loaded with 6,832 tons of cylinders containing mustard and lewisite, was scuttled 129 miles west of San Francisco's Fisherman's Wharf; the military insisted it posed no danger to humans or marine life. It carried out more dumpings at other locations as well, but never admitted the practice had created any hazard.[5]

During the 1950s, the United States had manufactured 400,000 M-55 rockets, each of which carried armaments that included 10.8 pounds of sarin nerve agent. By 1966 the Army had discovered that some of the rockets were leaking, so it launched Operation Chase ("Cut Holes and Sink 'Em") to deal with the problem. A total of 51,180 rockets laden with nerve gas, jet fuel, and other toxic components were encased in concrete and loaded onto three ships that transported them 150 miles off the coast of Atlantic City, New Jersey, where the ocean was 6,000 to 7,000 feet deep. Two of the ships were scuttled there; the effects of what happened when they reached the sea floor, and what resulted from the action of the water pressure, were anyone's guess. Then the team proceeded to sink the third ship, the *SS Richardson*. But as it fell to the bottom, its cargo of conventional high-explosive weapons and 3,500 1-ton containers of mustard agent mixed with water, underwent a chain-reaction explosion that burst the mustard from its protective sheaths, causing extensive pollution throughout the area that the waves and currents spread even farther. Another Operation Chase maneuver in 1970 involved the disposal of the equivalent of 39 railcars full of concrete-encased M-55 rockets loaded with GB nerve agent off the Florida coast.[6]

Prior to dumping the explosives and poison gas in oceans and seas, the Army did not consult with oceanographers or other scientific advisors about its procedures. The Army's planners also failed to take into account such basic factors as the velocity of the ships as they hit bottom with their poison-laden cargoes. Capt. T. K. Treadwell, commanding officer of the Naval Oceanographic Office, warned of the Operation Chase procedures, saying: "The results could be catastrophic." But his warnings were ignored.[7]

Most disclosures about the military's dumping practices did not become public until the 1990s or after. But long before that indications kept surfacing that the discarded poison gas was causing problems.

In the Adriatic Sea, from 1946 to 1966. at least five Italian fishermen died and more than 200 were hospitalized after catching U.S. mustard residue in their nets. Some of the fish they pulled up were found to have lesions and to contain elevated levels of arsenic, probably due to lewisite. The Italian government later identified numerous chemical weapons dump sites along the seabed.[8]

More long-term ocean hazards posed by chemical agents continued well after the war. Japan's sea problems from chemical weapons dumping began to surface in 1973, more than a quarter-century after World War II, when 85 fishermen were reported injured from chemical warfare waste.[9] In Australia, it was not until almost 60 years after the end of World War II that grave environmental problems were linked to the post-war dumping of more than 60 million pounds of chemical weapons off Brisbane.[10]

Finally, after the U.S. Army publicly admitted that it had dumped chemical weapons off the U.S. coast with insufficient safeguards, Congress moved in 1972 to explicitly ban the practice of offshore disposal of chemical warfare agents.[11] But scientific understanding of the consequences of what had already occurred was just starting to sink in.

Environmental concerns grew in 2001 when the U.S. Army revealed that it had actually dumped at least 64 million pounds of chemical warfare agents, as well as more than 400,000 mustard gas-filled bombs and rockets and more than 500 tons of radioactive waste, off the U.S. coast—and an even greater volume of poisons off the shores of other countries in Europe, India, and the Pacific.[12] But frustrations grew in those areas when the Army admitted it could not furnish precise details about the size, location and chemicals involved in most of the dumps, because it had never kept proper records. Even the known dump sites had never been monitored or checked. Today the Army acknowledges that some of its discarded chemical weapons are capable of causing serious harm for years to come.[13]

Although some experts have argued it is better to let sleeping dogs lie, others warn that the poisonous sea litter poses major hazards that may actually be increasing, not diminishing. Some of the crumbling containers are leaking toxic agents into the seawater. As the poisons enter the food chain, they deplete fish stocks and cause other serious damage to the aquatic environment; they also pose many direct hazards as well as possible long-range genetic consequences for humans.[14]

Fishermen and ocean scientists are particularly vulnerable, according to a study by ocean chemists Peter Brewer and Noriko Nakayama of the University of Tokyo. The researchers have pointed out that exposure to mustard can prove fatal.[15] Mustard blister agents are heavier than seawater and not very water-soluble. At colder temperatures such as those existing at many ocean depths, mustard tends to develop a hard polymer shell that encases the poison and seals it off from the seawater. This concentrated substance can last for years, killing or contaminating sea life as it bounces along the ocean floor and also preserving some poison for future mischief. Mustard's density makes it tend to remain on the ocean floor, which contributes to its long-term risk.[16,17] Researchers examining the long-term health consequences of exposure to mustard have found that it contributes to chronic bronchitis, conjunctivitis, skin ulceration, and other maladies; it can also damage DNA and cause cancer. Mustard's environmental effects have received scant attention, however. Some scientists estimate that mustard gas can have an active life of up to 100 years.[18]

In 1984, 11 Danish fishermen off the Baltic island of Bornholm suffered mustard burns from a former chemical weapons dump site. As a precaution, local fishing crews took to wearing protective suits and equipping their vessels with gas masks and special medical treatment kits. Latvia, Finland, and Russia conducted frequent surveys of the seabed to investigate possible contamination from leaking old chemical warfare shells.[19] Noting that steel containers corrode at different rates, nervous Danish authorities resorted to covering some shallow-water chemical weapons dump sites with concrete in an effort to try to contain the leakage. But saltwater corrosion may continue to cause the release of deadly chemicals for a century or more, causing unforeseeable environmental effects.[20]

From time to time, the poison rears its ugly head. Mustard is known to have injured hundreds of fishermen across the globe. In 1976 a dredger in Hawaii was seriously burned when he landed an old U.S. Army mustard-filled mortar round.[21] Almost 30 years later and more than 6,000 miles away, in the summer of 2004, a clam-dredging operation off New Jersey brought up another deteriorating artillery shell that was leaking some sort of mysterious tarlike substance. As a precaution, bomb disposal technicians from Dover Air Force Base in Delaware were summoned to deal with the ordnance. Although it did not explode, the shell injured three of the technicians, and one required hospitalization for large pus-filled blisters on his arm and hand. Subsequent tests revealed that the mysterious gel was discarded mustard gas that had hardened.[22]

A few researchers have been trying to come up with better ways to address the problems. In 2005, Czech scientists working on assignment from NATO announced they had invented an environmentally friendly enzyme-based technology that can eliminate the lethal effects of mustard gas. The researchers touted it as useful for helping to neutralize aging stockpiles and quantities of mustard that endanger the environment, adding that their new decontaminating agent may also help defend against a possible terrorist chemical attack.[23]

When released into the ocean, a nerve agent can last up to six weeks, killing every organism it touches before breaking down into non-lethal chemical components. Some experts contend that it can also cause longer-term damage.

Nobody has published studies examining the effects of chemical weapon leakage on the world's food supply. However, some of today's commercial fishing operations now must go ever farther from shore to make their hauls due to the depletion that has occurred at shallower depths. Scallopers, for example, now must dredge in up to 400 feet of water, which in some East Coast Atlantic areas may require them to go more than 100 miles from shore. This has major cost and safety ramifications. Leaking chemical weapons may be one reason why the once-abundant bottom-dwelling cod population of the Northern Atlantic has been decimated. In 1987, hundreds of dead bottlenose dolphins mysteriously washed up on Virginia and New Jersey shores, showing strange skin lesions that were later attributed to leaking chemical weapons. Ocean soil sediment tests in some areas have revealed high levels of arsenic, which many researchers trace to lewisite.[24] Lewisite is an arsenic-based blister agent that is faster acting and more deadly than mustard. Its only use is as a chemical weapon. Because it is denser than mustard and has a much lower melting point, it usually takes the form of a liquid in the ocean, and U.S. Army bulletins claim that lewisite quickly loses its blister agent properties when exposed to seawater. But some researchers contend that lewisite's degradation process also releases deadly arsenic into the sea. Bottom-feeding shellfish are more likely to become contaminated and pass arsenic up the food chain to accumulate in humans who eat them.

In 2007, Congress finally enacted legislation requiring the military to perform multiple remedial efforts in response to the problems associated with its dumping of chemical and conventional weapons off the U.S. coast.[25] It is still too early to tell if this law will begin to remedy the problem.

Human Guinea Pigs

Edgewood Arsenal was established in November 1917 as the United States Army's primary chemical weapons center. It housed extensive research, development and testing facilities and produced large quantities of phosgene, chloropicrin, and mustard gas, along with artillery shells to be used on European battlefields. At the time the location seemed ideal: it was set in rural Maryland, about 90 miles north of Washington, across the Bush River from the Army's oldest proving ground, Aberdeen, so that design and manufacture of vital ordnance materiel could be carried out near the nation's industrial and shipping centers. The area was off the beaten track and sparsely populated. Throughout its brief one-year wartime operation, Edgewood buzzed with activity and proved to be a crucial cog in the country's war machine, serving as a prodigious producer of lethal gases.

After the fighting ended, the arsenal enjoyed two decades of relative calm and tranquility before the threat of involvement in another world war caused what one writer called a "withered skeleton" to spring back to life, like a reawakened Frankenstein. Fearing that the war of the future would again involve every manner of chemical warfare and possible attacks against civilians, American military commanders retooled the old machinery to again make gas masks and protective clothing, test new chemical agent dispersal methods and defenses, and train military personnel.[26]

During World War II, Edgewood resumed intensive testing of chemical agents and countermeasures for possible use in the conflict. Workers at Edgewood tested and developed flamethrowers and smoke screens that would end up becoming widely used in both theaters of the war. By and large the arsenal's safety record was better than the one it had compiled in World War I. However, on May 25, 1945, a massive explosion ripped apart one factory building, killing 12 female workers and injuring 57 other staff that had been making incendiary bombs for the planned invasion of Japan.[27]

But there was more going on at Edgewood that escaped public attention. And it continued for decades, throughout World War II and the Cold War, even as the vicinity became much more densely populated.[28] Whiffs from some of the darker doings at the secretive site that served as America's chemical warfare nerve center would not begin to leak out until the 1970s. But it has only been since the 1990s or so that a more detailed historical picture has emerged about the scope and impact of the facility's human experiments on enlisted men, innocent civilians, and the environment. It stayed secret for so long because the participants remained tight-lipped for many years or even to the grave, out of loyalty to their country, innocence, or disability—while many have been plagued by nagging physical and psychological maladies.[29] Eventually, however, their story began to emerge.

Frank Cavanaugh left Yale in his junior year to serve in the Army in World War II. Assigned to Edgewood, he sustained mustard burns on several parts of his body from exposures in the arsenal's chemical testing chambers, then went on to command a chemical mortar unit in the Pacific. He later endured a 30-year struggle with squamous-cell cancer before dying on January 2, 2002—suffering that his loved ones later blamed on exposure he had sustained during his chemical warfare service. In 1999, another Edgewood veteran, Zenon Siepkowski, succumbed from respiratory failure after years of battling leukemia—health problems which relatives linked to his involvement in chemical warfare testing.

Details about service in chemical units were considered classified information, and many Edgewood veterans kept their secrets to the grave. Sometimes a family did not learn about their loved one's wartime experiences in Edgewood until the end, when they were sorting through his old papers or journal. Seven weeks before his death from acute myelogenous leukemia and lung disease, Albert Jasuta left a note that said, "See what happens when one has been involved with Army poison gasses?" Another vet, Al Felgendrager, suffered a nervous breakdown in 1955 and other maladies afterward, but the cause was unknown. His Army medical records did not mention that he had served in a chemical warfare outfit, much less did they disclose that he had been exposed to mustard agents and other poisons in Edgewood's gas chambers.

Many Edgewood victims did not realize the full nature of their chemical-related injuries until several decades had passed. By the early 1970s, however, as the WWII Edgewood veterans aged and sickened, more sufferers began to attribute their ailments to their participation in the chemical warfare experiments. But the Defense Department and the Veterans Administration thwarted any claims by simply denying that the experiments had ever taken place. Most veterans did not fight it; they just faded away.

But one survivor in particular continued to seek redress. In 1975, Nat Schnurman asked his physician why at age 50 despite his efforts to lead a healthy life he suffered from a host of nagging ailments. The physician, who had previously served at Edgewood, asked if he had ever worked around chemicals. It was then that Schnurman, a former sailor, began to reveal to someone for the first time his military experiences during WW II. As a 17-year-old recruit, he remembered, he had been put in Edgewood's gas chamber six times in seven days. The final time, his handlers had piped in a blend of poison gas that made him vomit into his mask and lose consciousness. The next thing he knew he was lying in a snow bank. After leaving the Navy, Schnurman recalled, his health steadily deteriorated, but whenever he sought treatment from the Department of Veterans Affairs, the bureaucracy denied he had ever been exposed to poison gas. Over time, however, he began to connect the dots.

More than a decade after speaking with his doctor for the first time, Schnurman learned more about mustard's effects. He read reports about Saddam Hussein's gassing of the Iranians and Kurds, then viewed a documentary film, "Keen as Mustard," that exposed how Australian veterans were contesting their government's program of human subjects testing in World War II. Then a Canadian journalist exposed Canada's World War II chemical warfare testing program. And shortly after that, the Richmond *Times-Dispatch* began publishing a series of articles about U.S. veterans who had been gassed. In 1991 Schnurman's saga ended up on "60 Minutes." The uproar increased as medical research studies surfaced that linked human chemical agent testing to a slew of illnesses, including respiratory and skin cancers, leukemia, chronic pulmonary disease, sexual dysfunction, and post-traumatic stress disorder.[30] Suddenly, the long-term effects of chemical warfare activities had become an international political hot potato.

Much of the renewed attention focused on Edgewood. After World War II ended, activity at the facility had scarcely slowed down before the Korean War, Vietnam, and the Cold War kept it hopping. For those who lived nearby, the small Maryland community was intimately connected to the ebbs and flows of poison gas research. One youngster, who lived there in the late 40s, before he turned ten years old, later left reminiscences about what it was like growing up in America's chemical warfare nerve center. Born in December 1940, Frank Zappa would eventually go on to become a famous musician and creator of the Mothers of Invention, but in those days he was just another local kid. Zappa's father was employed as Edgewood's meteorologist, literally assigned to determine which way the wind was blowing before the researchers released the chemical agents; he also earned extra money by volunteering for human testing of certain chemical substances. The Army called them "patch tests." Frank Zappa later recalled, "The Army didn't tell you what it was they were putting on your skin—and you agreed not to scratch it, or peek under the bandage—and they would pay you ten bucks per patch." His father sometimes came home with three or four patches he had accumulated that week. "I don't know what the stuff was," Zappa said, "or what long-range health effects it might have had on him (or on any of the children that were born after the time that they did it)."[31]

Living in the small government housing project attached to the base, Frankie Zappa's childhood toys included plenty of laboratory items such as glass beakers, Florence flasks, and blobs of mercury that he played with all the time—oblivious to the dangers they presented. "The entire floor of my bedroom had this 'muck' on it, made out of mercury mixed with dust balls," he later wrote. For fun he used to smash it with a hammer and watch it squirt over the floor. The family's closet contained bags of DDT, and gas masks for everyone in the family were hung on the hallway rack. Frankie used his mask as a space helmet. He also learned some of the fascinating finer points about gas warfare, such as the fact that "before they would squirt mustard gas onto a battlefield, they had some other stuff called chloropicrin, a dust that induced vomiting—they called it 'puke stuff.' " The youngster heard how "the dust would creep around the edges of the soldier's mask, causing him to vomit. If he didn't take his mask off, he could drown in his own spew, and *if* he did—to let the chunks out—the mustard gas would get him." When he was ten, the boy's asthma and other ailments became so bad the family moved to California. Frank Zappa often incorporated Edgewood into his music and public persona. In 1991 he was diagnosed with prostate cancer; he died at age 52.[32]

Many of the most secret and bizarre experiments were conducted at the behest of the CIA. It later came out that some of the researchers included nine former Nazi scientists, who had been brought to the United States with rocket specialists and other German assets under Operation Paperclip. One of them was Otto Ambros, the former Nazi chemist for IG Farben who at Nuremberg had been convicted of slavery and mass murder of Jews at Auschwitz and sentenced to eight years in prison. But because Ambros was a leading figure in Germany's chemical warfare program, where he had helped to develop its early nerve agents and other wonder weapons, America's High Commissioner of Germany John J. McCloy commuted his prison sentence in order that the former war criminal could serve the American military. Ambros was hired by W. R. Grace & Co. and secretly hustled off to Edgewood, where he continued his chemical warfare research for the United States.[33]

The Army tested all sorts of biological and chemical warfare agents (including LSD and other mind-altering drugs) at Edgewood. Rats and goats were not the only testing subjects. From 1955 to 1975, the Army researchers tried out all kinds of dangerous chemical agents on 7,000 enlisted men who served as human guinea pigs in elaborate experiments that were sometimes filmed. The medical volunteers ("med vols") were young, healthy males who had met relatively high standards of physical and mental performance. They were never told what substances were being tested on them or what likely effects to expect. However, they were assured that the experiments were "safe"—so safe there would not be any bothersome need for follow-up. Many of the tests to which they were subjected were extensively measured, recorded, photographed and filmed, but they never got to see any of the records or data. Nobody realized the long-term health consequences.

During one series of tests conducted from 1965 to 1969, an undisclosed number of U.S. enlisted men wearing gas masks were subjected to open-air releases of sarin or VX. Strict secrecy rules demanded the soldiers were never told what nerve agent was involved and facts about the tests were not disclosed until 2002. The Edgewood tests were part of a much larger program of human experimentation that the U.S. military and some of its allies conducted in several countries, which was code-named Project 112. Their purpose was to study the effectiveness of equipment, procedures and tactics, "not to test the effects of dangerous agents on people," Dr. William Winkenwerder Jr., the assistant secretary of defense for health affairs under Donald Rumsfeld, later claimed. Military spokespersons insisted that none of the lethal agents released during the tests had ever endangered any surrounding communities.[34] Some of the VX nerve agent tested at Edgewood involved M23 land mines. All soldiers who were exposed to the agent wore "complete, impermeable butyl-rubber outfits and M9A1 masks," according to the Department of Defense. Their protective clothing and vehicles were later tested to detect any remaining nerve agent.[35] In the spring of 1969 additional chemical agent tests were carried out at Edgewood to measure the effects of VX, tabun, sarin, and soman. They were part of an even larger program called "Rapid Tan."[36]

Edgewood's physical plant and procedures progressed during the Cold War to become more consistent with high-level research conducted in other settings, according to Dr. James S. Ketchum, a psychiatrist who worked there in the 1960s and later self-published a book about his experiences. Ketchum's memoir depicts a highly educated professional staff in white shirts, ties, and white lab coats, who constantly worked to improve their equipment, adding such innovations as closed-circuit TV to record drug tests and padded rooms to prevent injuries. He includes a photograph showing Edgewood's civilian head, Dr. Van M. Sim, breathing sarin gas—something Sim reportedly insisted on doing for every other substance before he allowed it to be administered to soldiers.

Ketchum wrote his detailed account after the September 11, 2001, and the anthrax attacks had focused renewed attention on chemical and biological warfare, and he says he was surprised that the U.S. government quickly approved his manuscript for publication, given all of the secret military information it contained. In his book he staunchly defends both chemical weapons and the use of human experimentation as he and others practiced it at Edgewood, saying it was done for worthwhile reasons and with adequate safeguards.[37]

But other staff who worked at Edgewood in the 1960s or 70s have gone on record to paint a different picture from the one left by Dr. Ketchum. Col. Albert Driesbach of the U.S. Army Medical Corps, who served as director of research under Dr. Sim, committed suicide shortly after leaving Edgewood.[38] Another psychiatrist, Malcolm B. Bowers, Jr., who served at Edgewood 1959–62, later published a fictionalized account of life at the arsenal. In it he describes soldiers used as guinea pigs in tests of highly lethal VX neurotoxin, which in one instance resulted in a fatal overdose of a delirious Army private by atropine antidote. In an interview for a Yale University publication, Bowers confided he was struck by the lack of informed consent in that era. The 30 soldiers recruited for month-long rotations had no idea what they were getting into. "They came to get a break from their bases and to check out the infamous bars along the harbor in Baltimore," he said.

Another psychiatrist who also served at Edgewood during the same era, Dr. George K. Aghajanian, later went on record to say that Bowers's U.S. account rang true as far as he was concerned. "It's not fiction," he said, "Just the names are fictional."[39]

Wray C. Forrest formed his opinions about Edgewood's human-experimentation program the hard way: he was one of the 6,270 servicemen who were human test subjects at the facility between 1950 and 1975. In 1973, the then 23-year-old recruit Forrest volunteered to participate in a program at Edgewood that promised a four-day work week and other attractive fringe benefits. Forrest says when he arrived he was given a new identity as Research Subject #6692. "That was the number assigned to me," he says, "similar to the numbers assigned to the Jews in the concentration/death camps in Germany during WWII." He adds: "We were never informed as to exactly what we were being given. We also did not sign any informed consent prior to the testing. This was a direct violation of the Geneva Convention rules for the use of humans in chemical and drug experiments/research."[40]

In May 1974, Mike Bailey was only 18 years old when he volunteered to participate in tests at Edgewood. He arrived for duty in June and left after completion of his 60-day tour. "After we processed into Edgewood," he said, "every day we would go to a day room to rest and watch TV. First they tested us, timed our performance on various exercises, when we were straight. Some days they put us into a self-contained gas room for hours and monitored our reactions to see how it differed from when we had been straight."

As Bailey tells it, "One day we were doing an exercise in Army fatigues and boots, wearing gas masks, and going under barbed wire. Alongside us there were technicians in fully protective moon suits. We were getting dosed with something—I don't know what. Somehow as I went under the wire, a barb caught my fatigues and my skin became exposed. Next thing I knew, a technician rushed over and jabbed a needle full of atropine into my right leg. Wham! Wham! It was so fast, I didn't know what happened. Just felt the two burning pains in my leg, like hornet stings. Next thing I knew they were decontaminating me. Everybody had on white coats." (Nerve agents such as sarin and VX block the nervous system's "off" message to muscles, causing extremely painful muscle spasms, until a breakdown of the respiratory system finally results in death. Atropine sulfate can serve as an antidote by restoring the "off" message to the muscle systems. But it must be administered immediately. At Edgewood atropine was usually injected into the leg by means of an autoinjector.) Bailey was lucky he got it in time. But beginning in 1994, he tells me, he began to experience heart attacks, strokes, skin problems, emphysema, and other problems that he attributes to his exposure to nerve agents and other harmful chemicals.[41]

After the terrorist attacks of September 11, the Army accelerated its neutralization schedule for the remaining chemical agents stored at Edgewood. Chemical agent disposal was commenced in 2003, and destruction operations were completed in February 2006. Then the facility entered its closing phase.

Nevertheless, some long-lasting damage to the environment remained. Since 1990 the U.S. Environmental Protection Agency has identified the 13,000-acre Edgewood area as a Superfund site in need of extensive cleanup due to a long list of dangerous toxic contaminants. As of 2003, the EPA reported that 32,315,778 cubic yards of soil or other solid-based media—roughly equivalent to 23.5 Empire State buildings—had been treated, stabilized, or removed; 86,060 gallons of water or other liquid-based media—amounting to 24.5 tank trucks—had been treated, stabilized, or removed; and 50 people had been relocated to prevent them from being exposed to contaminants. The EPA has added, "People who accidentally ingest or come in direct contact with contaminated groundwater, surface water, soil, or sediments may be at risk."[42]

Chemical Weapons Control

During the Cold War more nations joined the chemical warfare club. In 1984, U.S. officials said they believed the threat of chemical weapons around the world was "very high," much higher than any threat of nuclear war. At the same time, the Reagan administration assisted and encouraged chemical weapons production and rearmament by the United States and its allies, ostensibly to create a deterrent against its enemies, while also demanding arms control mechanisms to ensure inspections of facilities suspected of the illicit development, production or storage of chemical arms. Then, after the fall of the Soviet Union, the George H.W. Bush administration called for a global ban on chemical weapons as a negotiating strategy.[43]

Finally, on November 30, 1992, after 70 years of outcries and a decade of protracted and painstaking negotiations, the Conference on Disarmament agreed to the text of a worldwide chemical weapons ban, which the UN General Assembly adopted at its 47th session. The resolution was entitled "Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction." The United Nations hailed it as the first disarmament agreement negotiated within a multilateral framework to provide for the elimination of an entire category of weapons of mass destruction. It was also the first multilateral arms control and nonproliferation treaty to regulate private companies widely. Thus it represented a major step forward for arms control. But it was not without its loopholes.[44]

In January 1993, 130 nations including the United States and Russia gathered in Paris to sign the treaty known as the Chemical Weapons Convention (CWC). The agreement is administered by The Organization for the Prohibition of Chemical Weapons (OPCW), an independent organization which conducts inspection of military and industrial plants in all of the member nations and works with countries having stockpiled chemical weapons.

Under the Convention, all participating states are prohibited from all development, production, acquisition, stockpiling, transfer, and use of chemical weapons. Each state is required to destroy all of its chemical weapons and chemical weapons production facilities, even if they were abandoned in another state. The verification provisions not only affect each state's military sector; they also apply to the civilian chemical industry, worldwide, by imposing certain restrictions and obligations regarding the production, processing and consumption of specific chemicals that can be used to make chemical weapons. Each nation's declarations must be verified, both by reporting requirements and by on-site inspections, some of which may be conducted on short notice.[45]

Article II defines the terms and criteria to be used in implementing the Convention. The items covered include "chemical weapon," "toxic chemical," "precursor," "old chemical weapons," "abandoned chemical weapons," "riot control agent," and "chemical weapons production facility." The CWC lists three schedules of chemicals that distinguish between toxic chemicals which can either be used as weapons or diverted from legitimate industrial use to help manufacture such weapons (i.e., used as precursors). The treaty establishes a mechanism to set quantities of the affected chemicals that can be produced commercially for legitimate purposes. Each class is split into Part A: chemicals that can be used directly as weapons, and Part B: chemicals useful in the manufacture of chemical weapons.

- **Schedule 1** chemicals have few or no known legitimate uses other than as chemical weapons. Examples include mustards (both sulfur and nitrogen), lewisite, nerve agents (sarin, tabun, soman, VX), ricin, saci-toxin, and substances (such as alkyl, methylphosphonyldifluoride, chlorosarin) which are solely used as precursor chemicals to manufacture chemical weapons. A few such chemicals have very small-scale non-military applications, such the use of minute quantities of nitrogen mustard to treat certain cancers. The Convention allows these types of chemicals to be produced or used for research, medical, pharmaceutical or chemical weapon defense testing purposes, but production above 100 grams per year must be declared to the OPCW. Possession of such chemicals is limited to a maximum of one ton.
- **Schedule 2** toxic chemicals are considered have legitimate small-scale industrial applications. Examples include amiton, PFIB, BZ. Any manufacture of these chemicals must be declared, and there are restrictions on export to countries which are not CWC signatories. Numerous precursors are also covered. Some of these include thiodiglycol, arsenic trichloride, dimethyl methylphosphonate, pinacolyl alcohol, and several others.

- **Schedule 3** chemicals can have large-scale legitimate industrial uses apart from chemical weapons. Examples include many of the most lethal substances used in chemical warfare, such as hydrogen cyanide, cyanogen chloride, chloropicrin, and phosgene. The 17 precursors that are covered include triethanolamine, sulfur monochloride, and many others. Plants which manufacture more than 30 tons per year must be declared and are subject to inspection, and export to countries which are not CWC signatories is also restricted.[46]

As of July 12, 2007, 182 of the 195 states recognized by the United Nations had joined the Convention. By May 21, 2009, the number had grown to 188, and the number of nonsigners was reduced to five. The five states that had not signed the treaty included North Korea, Egypt, Syria, Somalia, and Angola.

In April 30, 2007. six member countries had declared stockpiles. These included the United States, Russia, India, Albania, Libya, and an unidentified "state party." Countries which had declared having chemical weapons production facilities included the United States, United Kingdom, Bosnia and Herzegovina, Serbia and Montenegro, France, Russia, China, India, Japan, Iran, Libya, and a "state party." However, several nonmember countries (especially Syria and North Korea) were suspected of having chemical weapons; at least two member states (Sudan and China) were suspected of failing to disclose their stockpiles.

By 2007, all of the declared chemical weapons production facilities had either been destroyed (42) or converted to civilian use (19). The treaty set up timetables leading to the complete destruction of chemical weapons, which was supposed to occur in 2007. By early 2006, however, only 19 percent of known chemical weapons stockpiles had been destroyed worldwide, and by early 2007 the number had risen to slightly more than 30 percent of 8.67 million declared chemical munitions and containers. As of August 2009, the holders of the world's largest stockpiles, the United States and Russia, continued to lag behind schedule in their destruction of weapons.

In the United States, the first facilities designated to destroy chemical agents under the treaty were the Johnston Atoll Chemical Agent Disposal System in the North Pacific and the Tooele Chemical Agent Disposal Facility in Utah. Further stockpile disposal facilities operated at The Aberdeen Chemical Agent Disposal Facility in Maryland; Pine Bluff Binary Destruction Facility in Arkansas; Anniston Army Depot, Alabama; Newport Chemical Depot in Indiana; and Umatilla Chemical Depot in Oregon. Additional disposal facilities were under construction in Pueblo Chemical Depot, Colorado, and Blue Grass Army Depot in Kentucky.

In June 2007, the Army Chemical Materials Agency announced that 45 percent of the U.S. chemical weapons stockpile had been safely destroyed.[47] As of 2009, however, the United States did not expect to complete its destruction until April 29, 2023. Russia, meanwhile, still had 28,000 metric tons left to eliminate.[48]

"Non-Lethal Incapacitating Gases"

Despite all of its positive features, the Chemical Weapons Convention contains numerous shortcomings and loopholes. For example, it was designed to deal with use of chemical weapons by government states, not by terrorist groups or religious cults. Another area not fully addressed by the ban has involved "non-lethal incapacitating gases," which the Convention allows for "domestic law enforcement" purposes.

In January 2008, a controversy arose after it was revealed that a private security contractor, Blackwater Worldwide, had dropped CS gas from a helicopter onto civilians and military personnel in Baghdad, temporarily blinding and choking dozens of persons on the ground. The U.S. State Department later said that its lawyers had concluded that the Blackwater incident had not violated any treaty agreements. Secretary of State Condolezza Rice authorized a written statement saying the international chemical weapons convention "allows for the use of riot control agents, such as CS, where they are not used as a method of warfare. The use of a riot control agent near a checkpoint at an intersection in the circumstances described is not considered to be a method of warfare." But others questioned any such use of CS in the war zone.[49]

The era's most highly publicized incident involving non-lethal incapacitating gas occurred in Russia. In October 2002, world attention was riveted on a tense hostage drama in the Dubrovka Theater in the heart of Moscow, only a few blocks from the Kremlin. A small force of 41 heavily armed and uniformed Chechen guerilla fighters held more than 800 civilians hostage in the fashionable theater and threatened to kill them all unless the Russian government met their political demands to negotiate an end to the war in Chechnya, withdraw Russian forces from their land, and grant Chechen independence. Russian federal security troops surrounded the theater, and government authorities under President Vladimir Putin refused to bargain, seemingly leaving the fate of the hostages in the hands of the separatist Islamic Suicide Squad, whose members had rigged themselves with explosives. Many of the hostage-takers were Chechen women who had lost their husbands and other loved ones in the protracted war for control of their country. No one doubted that they and their male comrades, led by the brutal Chechen commander Movsar Barayev, were willing to kill and die for their cause. After 57 fruitless hours, it appeared that a mass slaughter was imminent. Many of the Chechens had not slept, and the extreme stress had pushed many of the water-and food-deprived hostages beyond their ability to cope. Some bystanders wondered if the authorities would somehow be able to pull off a miraculous rescue such as occurred with the famous 1976 raid on Entebbe when Israeli Defense Forces had staged a lightning-fast surprise commando attack in Uganda that saved all but three of the 106 hostage passengers being held by terrorists.

Shortly before sunrise on Saturday, however, the Russians unleashed a surprise of their own as they suddenly began pumping a mysterious aerosol into the theater. Before many of the hostage-takers could shoot or detonate their bombs, a thick, light gray gas engulfed the auditorium, immediately causing many of those inside to collapse into their seats. Simultaneously, the Russian commandoes staged a violent strike. Although two hostages and several of the hostage-takers were quickly shot during the charge, mass bloodshed from the explosive bombs was somehow averted, and it initially appeared that the security forces had pulled off one of the greatest armed rescues in modern history.

Within hours, however, it turned out that 129 hostages had died—all but two of them apparently from the gas—and hundreds more had been hospitalized in serious condition as a result of the mysterious aerosol spray that had been pumped into the theater. Media reports quickly established that the Russian government had utilized some sort of non-lethal, incapacitating chemical agent, which at first was described only as an "anesthetic," like the ones used in general surgery.

For three days after the raid, Russian officials refused to identify the specific gas they had used, leaving some military experts to speculate that it may have been BZ (3-quinuclidinyl benzilate), an incapacitating superhallucinogenic agent that the U.S. military had secretly developed for combat during the Cold War.[50] If it was BZ, its use probably would have violated the Chemical Weapons Conference to which Russia was a signatory.

A story in *The New York Times* quoted unnamed American officials as saying they suspected Russian security police had employed an aerosol version of a powerful, fast-acting opiate in an attempt to instantly anesthesize Chechen extremists and prevent them from killing the hostages. This too would seem to amount to a violation of the chemical weapons treaty.

Any use of non-lethal incapacitating gas also raised all kinds of national security issues, for the Americans as well. American military officials had said in 1997, "incapacitating munitions are no longer in our armamentarium." But as the *Times* story noted, in 2000, researchers at the Institute for Emerging Defense Technologies at The Pennsylvania State University had also reported: "the development and use of non-lethal calmative techniques is achievable and desirable." Questions still remained about which agent the Russians had used.[51]

Finally, four days after the raid, Russia's health minister, Yuri Shevchenko, publicly acknowledged the gas in question was indeed based on derivatives of fentanyl—an opiate-based narcotic. The American Society of Anesthesiologists described it as a narcotic that is 100 times more powerful than morphine, and commonly used in the United States for pain relief in surgeries.[52]

But the Russians' use of fentanyl seemed suspect on other grounds as well. American anesthesiologists use fentanyl to stop breathing during heart surgery when breathing is mechanically supported. The Centers for Disease Control and Prevention said high doses of the gas can be fatal; it can also cause liver, heart, and kidney problems as well as nausea and vomiting. Medical experts also pointed out that a person who vomits while unconscious may choke to death, and that was apparently what had happened to some of the Moscow victims.[53]

"I couldn't see and taste it," one former hostage said, "but after this gas, I laid on the floor . . . and I remember nothing except I woke up in the hospital." Another survivor told CNN, "I am very tired. When I awoke in the hospital I couldn't understand what had happened to me because I was unconscious for 10 hours."[54]

Under the circumstances, the Russian public and world public opinion accepted the use of fentanyl as a lesser evil that was intended to save the lives of innocent hostages. International criticism of Russian authorities was relatively muted, and many observers actually supported the use of non-lethal, incapacitating gas as an alternative to brute deadly force—even if the gas had proved lethal to many of those it was intended to save. For the time being, the status of so-called non-lethal incapacitating gases slipped back into relative obscurity.[55]

The Moscow episode was not the only instance in recent times in which a supposedly non-lethal incapacitating gas had inadvertently resulted in deaths during a siege. The federal assault on the Branch Davidian compound in Waco, Texas in 1993 that killed 76 persons, including 21 children and two pregnant women was later shown to have involved pyrotechnic CS (tear gas) that had started raging fires.[56] Incidents such as Waco and Moscow have underscored the fact that "non-lethal incapacitating agents" can prove to be a deadly chemical weapon of war if used in high concentrations.

Chapter 16

From Stink to Extinction: Methane (CH_4), Carbon Dioxide (CO_2)

This goodly frame, the Earth, seems to me a sterile promontory; this most excellent canopy, the air, look you, this brave o'er-hanging firmament, this majestic roof fretted with golden fire, why it appears no other thing to me than a foul and pestilent congregation of vapours.

—William Shakespeare, *Hamlet* (act 2, scene 2)

About 9 A.M. on January 8, 2007, an odor like rotten cabbage wafted over parts of Manhattan and northeastern New Jersey. The stink became so pervasive that thousands of worried residents called 911 and Homeland Security alert procedures went into effect. Inquisitive TV and radio crews, showing their nose for news, rushed to ask if the smell might signal a flammable natural gas leak or a terrorist attack, prompting New York Mayor Michael Bloomberg to hurriedly call a press conference to announce there was no cause for alarm. After a dozen dizzy New Yorkers ended up in hospital emergency rooms, the MTA (Manhattan Transit Authority) suspended service in some stations, and two public schools were briefly evacuated, many wondered, what was the cause? Was it dangerous? Was New York under attack? Only four months earlier, lower New York had experienced a strong odor resembling maple syrup or caramel, and five months before that a different mysterious smell had blanketed the area; now this. What on earth was the problem?

Environmental scientists identified the likely culprit as gases released from saltwater marches in the metropolitan area.[1] A number of reports specifically cited methanethiol (also known as methyl mercaptan or swamp gas), a colorless vapor that often emanates from decaying organic matter in marshes; it is also commonly present in natural gas, crude oil, animal feces, and sewage. Methanethiol also exists in certains foods such as nuts and cheese and is used in several industries such as plastics and animal feed. The United States Material Safety Data Sheet lists it as a flammable gas that gives off an extremely strong and repulsive smell when it reaches high concentrations. Although little is known about its health effects, a very high concentration is quite toxic and affects the central nervous system.[2]

Following the latest incidents, New York City officials assured the public they regularly monitor the air to detect the presence of chemical, biological or radiological substances; they said there was nothing to worry about. But the officials would not release any data from their air-quality readings.[3]

The New York metropolitan area was not the only place to have experienced such an olfactory mystery. On December 26, 2005, dozens of customers and staff at a home supplies chain store in St. Petersburg, Russia became ill when gas suspected to be methanethiol was somehow released. Somebody suggested the store may have been targeted for sabotage, but no definitive finding was ever reached. Once again, the source of a mysterious stink remained unsolved.[4]

Accounts about swamp gas (also known as marsh gas, *ignisfatuus*, will-o'-the-wisp, or jack-o'-lantern) have spanned the globe for centuries. Many descriptions have involved slow-moving black water rivers flowing through rain forests and wetlands, scattered swamps, marches, peat bogs, or mud flats—watery places in the Amazon, the Orinoco Basin, and parts of the American South where organic matter from dead plants and trees commonly decays in stagnant water. Observers have often noted its strange characteristics, as in the following account from 1832 when a traveler in Newmark, Germany reported:

> The water of the marsh is ferruginous, and covered with an iridescent crust. During the day bubbles of air were seen rising from it, and in the night blue flames were observed shooting from and playing over its surface. As I suspected that there was some connection between these flames and the bubbles of air, I marked during the day-time the place where the latter rose up most abundantly, and repaired thither during the night; to my great joy I actually observed bluish-purple flames, and did not hesitate to approach them. On reaching the spot they retired, and I pursued them in vain; all attempts to examine them closely were ineffectual. On another day, in the twilight, I went to the place, where I waited the approach of night; the flames became gradually visible, but redder than formerly, thus showing that they burnt also during the day; I approached nearer and they retired. Convinced that they would return again to their place of origin, when the agitation of the air ceased, I remained stationary and motionless, and observed them again gradually approach. As I could easily reach them, it occurred to me to attempt to light paper by means of them, but for some time I did not succeed in this experiment, which I found was owing to my breathing. I therefore held my face from the flame, and also interposed a piece of cloth as a screen; on doing which I was able to singe paper, which became brown-colored, and covered with a viscous moisture. I next used a narrow slip of paper, and enjoyed the pleasure of seeing it take fire. The gas was evidently flammable, and not a phosphorescent one, as some have maintained.[5]

Locals around Georgia's vast Okefenokee Swamp in the United States often report encountering eerie forms and sounds coming from the swamp at night. The area emits popping sounds of swampy flatulence that can amaze an unsuspecting visitor. Nocturnal balls of glowing purple and white balls seem to skip and bounce over the bog. Popularly known as "foxfire," the bioluminscence is created by a fungus that sometimes grows on wet, decaying wood. Benjamin Franklin recommended it to light the interior of a primitive submarine during the American Revolution. Mark Twain had Huckleberry Finn and Tom Sawyer use its green glow to illuminate a secret tunnel they dug in *The Adventures of Huckleberry Finn*. Ancient Greek, Roman and Indian texts all referred to it. Pliny the Elder identified an *agaricke* that "grows on the tops of trees and shines at night." In Elizabethan times, Shakespeare wrote of it as "fairie sparks."[6]

But swamp gas is not always so entrancing. Twentieth-century scientists found swamp gas to contain methane (CH_4), an odorless, colorless, and highly flammable gas that is lighter than air. The gas often burns with a pale blue or yellow flame.[7] Recently some scientists have made startling discoveries regarding its link to global warming. In 2004, a study published in the research journal *Science* reported that a 22-member team of American and Russian scientists had spent three years conducting radiocarbon dating drilling and other tests in the world's largest peat bogs in the Siberian Arctic. What they found shocked them.

Peat is a kind of moss that forms in cool, wet regions, where cold temperatures normally keep dead plant material from fully decomposing. Thousands of years ago, the Siberian peat built up in layers, forming an area that is now roughly the size of Germany and France combined. Before becoming frozen, the bogs had absorbed and held vast amounts of carbon dioxide, comprising one of the world's great stores of carbon and a huge volume of methane as well. But recently, due to global warming, this tundra has begun to thaw. Tests indicate that the Siberian bogs have begun to melt for the first time since their formation about 11,000 years ago, and this thawing has serious climate ramifications. Now, where the formerly frozen ground has turned soggy anaerobic bacteria are producing large volumes of methane gas. This is worrisome because methane and carbon dioxide are the leading "greenhouse gases" that trap heat in the Earth's lower atmosphere. Methane is not as abundant in the atmosphere as carbon dioxide, but considering its volume it is more effective than carbon dioxide in causing climate warming. Prior to the recent Siberian bog discovery, environmental scientists had known for some time that the Earth's atmosphere was showing a significant rise in methane gas. But many scientists had attributed it to releases from the seafloor and emissions from ravaged tropical rain forests.

The Russian explorations revealed that the current ongoing thawing of the Siberian permafrost has also begun releasing large amounts of trapped methane into the atmosphere, thereby contributing still more greenhouse gas, which nobody had yet worked into their global warming calculations. This has resulted in even more alarming climate scenarios than the environmentalists had envisioned.

The world's peatlands contain an estimated 550 billion tons of stored carbon. The *Science* study noted that the West Siberian Lowland alone accounts for 7–26 percent of global carbon reserves accumulated since the last Ice Age, prompting some researchers to estimate that a complete thaw there would release billions of tons of trapped methane into the atmosphere, possibly contributing to a major and unexpected shift in climate trends. This might add up to another example of a "tipping point" that climate scientists have feared—something that could upset a delicate ecological threshold wherein a slight rise in the Earth's temperature can cause a dramatic change in the environment that triggers a still greater and cataclysmic warming of global temperatures. Findings in northern Russia indicated such a process may already be about to start: sea ice was melting faster than ever, the permafrost was diminishing and new shrubs were sprouting up, and the tree line was shifting northward into areas that had previously been covered with ice.[8]

In 2005, Sergei Kirpotin at Tomsk State University concluded that the thaw of the West Siberian permafrost had probably just begun in the past three or four years, and he termed the situation an "ecological landslide that is probably irreversible and is undoubtedly connected to climatic warming."[9]

Siberia is not the only area of the globe to be experiencing such a melt. Peatlands cover 12 percent of Canada, and the conservation group Wildlife Habitat Canada also warned that climate-change modeling studies for the foreseeable future forecast very severe warming of Canada's peatlands much like the thaw that has been going on in Siberia.[10]

In 2001, the Intergovernmental Panel on Climate Change raised alarm when it predicted a rise in global temperatures of 1.4°C–5.8°C between 1990 and 2100 and noted how such a warming would have catastrophic effects on the planet.[11] That estimate, however, only took account of global warming driven by known greenhouse gas emissions; it did not figure in further natural releases of gases from western Siberia and other thawing peat bogs.

Therefore, the Siberia findings generated additional dire warnings from global warming activists. Larry Smith, a hydrologist at UCLA, argued that even if western Siberia permafrost thawed slowly, allowing the methane to gradually seep into the atmosphere over the next 100 years, this would still add 700 million tons of carbon dioxide into the atmosphere per year, thereby increasing global warming by a factor of 10–25 percent. And Tony Juniper, who was then director of Friends of the Earth, said the Siberia data should convince politicians to take concerted action on climate change before it is too late. "If we don't take action very soon," he warned, "we could unleash runaway global warming that will be beyond our control, and it will lead to social, economic and environmental devastation worldwide."[12]

Thaws were not the only threat posed by peatlands. About the same time as the Siberia reports, another researcher warned the Royal Geographic Society that farmers' rampant burning of tropical peat bogs in Indonesia was accounting for up to a seventh of the world's annual total fossil fuel emissions. Calling tropical peatlands one of the largest stores of carbon on the Earth's surface, Professor Susan E. Page of England's Leicester University noted that Indonesians had taken only eight years to burn away an area of peatland the size of Belgium, mainly to make way for rice plantations, thereby contributing on a grand scale to global warming.[13] This tropical peat bog study added more fuel to the environmentalists' fire regarding the role of peatlands in generating greenhouse gases.

What makes such findings all the more worrisome is that methane has been linked to a number of previous extinctions on Earth, according to several prominent new scientific theories. Based on recent studies, some experts now believe that Earth already has experienced five extinctions, and we may now be undergoing the sixth; levels of CO2—which has figured in some previous global climate catastrophes—have not been this high for 40 million years, and they are growing again at a rapid rate. The overwhelming consensus among scientists is that the current crisis is largely due to anthropogenic (man-made) factors. Scientists also agree that global warming/climate instability is apt to produce a variety of deleterious results: storms, floods, heat waves, desertification, famine, disease, and ultimately species extinction.[14] American concerns about some of these implications increased after Hurricane Katrina devastated New Orleans in August 2005, and they have been growing in parts of Africa, Asia and the Pacific islands as well. World attention further intensified with the Copenhagen Climate Conference in December 2009.

The mass extinction of the dinosaurs that took place between the Mesozoic and Cenozoic eras, about 65 million years ago, is often referred to as the K-T extinctions. In 1999, Burton Hurdle and his colleagues at the U.S. Naval Research Laboratory asserted that the end of the Cretaceous period featured the release of huge amounts of methane gas from rotting vegetation trapped in sediments more than 500 meters below sea level. Cold temperatures and high pressure allowed the methane that was escaping from the depths to combine with water to form a solid substance, such as is occurring today off the coasts of the United States, Japan, and Germany. The authors argued that an asteroid or comet colliding with the ocean floor at that time generated huge shock waves that shot around the planet, thereby freeing still more vast quantities of trapped methane. Lightning bursts may have ignited the methane-rich air, triggering firestorms that set the atmosphere ablaze and finally brought about the dinosaurs' demise.[15]

An alternate hypothesis for the K-T extinctions, which also involves gas, contends that at least 1 million cubic km of lava suddenly erupted at India's Deccan Traps. This unleashed a huge volume of sulfur acid aerosol, resulting in extreme environmental conditions that ultimately led to the mass extinctions. Gases have also figured in alternate K-T extinction theories.[16]

The most severe extinction event of all time is the Permian extinction event of 250 million years ago, that occurred between the Permian and Triassic geologic ages, when more than 90 percent of all earthly species apparently became extinct. One hypothetical cause of this event was climate change initiated by CO_2 release from volcanoes in what is now Siberia; according to this theory, as the methane hydrate deposits in the oceans thawed, the resultant warming may have triggered explosive releases known as methane "burps."[17]

A computer simulation of the Earth's climate 250 million years ago has been introduced to support the theory that global warming triggered the so-called "great dying." In 2005, scientists at the National Center for Atmospheric Research in Boulder, Colorado reported data indicating that extensive volcanic activity over the course of hundreds of thousands of years released into the air huge amounts of carbon dioxide and sulfur dioxide that gradually warmed up the planet. The CO2 caused temperatures to soar to 10°C–30°C higher than today, according to Jeffrey Kiehl and his colleagues, who published their findings in *Geology*.[18] Their studies suggest that global warming also had a profound impact on the oceans, extinguishing most life forms in the sea as well as those on land.[19]

Still another, even more recent, theory was presented by a team of international scientists in the Proceedings of the Russian Academy of Sciences. It held that the great mass extinction 250 million years ago could have been triggered, at least in part, by halogenated gases from giant salt lakes like the Zechstein Sea.[20]

In short, researchers have only lately begun to determine the full number of previous extinctions on Earth and to uncover the role that various gases, especially methane and carbon dioxide, played in bringing them about. Yet most extinction theorists already agree about one thing: gases played a key role in virtually every extinction scenario in the past, and they likely will do so again.

Helmont's decision to name gas after the ancient Greek word for chaos reflected his early recognition of its wild and unpredictable nature. But besides being the dark void from which all things in the universe came into being, as the ancients had envisioned, its chaos may presage the end as well as the beginning. For gases have gone on a global rampage before and they will do so again—particularly since human beings from the time of the Industrial Revolution have added such a boundless host of gases that are creating additional havoc in the world.

Several science fiction writers ushered in the twentieth century with doomsday accounts featuring lethal gases. H.G. Wells, in one of the first great apocalyptic novels, *The War of the Worlds* (1898), portrayed Martians using a super-potent chemical weapon known as "the black smoke." A few years later, another popular work propelled cyanide gas into the public's apocalyptic imagination. In M.P. Shiel's *The Purple Cloud* (1901), a poisonous cloud of cyanogens belched from a volcano in Southeast Asia exterminates humankind as punishment for its meddlesome efforts to unlock the secrets of the universe. And writing just a year before the outbreak of World War I, Sir Arthur Conan Doyle penned *The Poison Belt* (1913), in which a character named Challenger sends telegrams asking three colleagues to join him at his home outside of London. His cryptic message instructs each person to bring a tank of oxygen. Upon arrival, Challenger has them ushered into a sealed chamber, whereupon he reveals that the Earth is about to succumb to a belt of poisonous ether that will extinguish the human race—but the airtight chamber and oxygen will save them. (In the end, the ether's effect proves only temporary and the world wakes up—but that is all science fiction.)

The chemical warfare onslaught of the Great War, followed by the Second World War with its hideous gas chambers and atomic bombs, bore out concerns about some such speculative fictions. Not to mention the avalanche of insecticides into the world's food supply, the rampant pollution of the air with carbon gases, and poisoning of the seas around us. Once again, science fiction writers may have been on to something important before any conventional scientists realized what was happening.

Our future may be grim. If it is not the fatal airs unleashed by primordial volcanoes and earthquakes that kill us, or the carcinogenic gases seeping into our homes from below, maybe it will be the deadly poisons concocted in scientific laboratories for military or industrial purposes, or the combustion-fed greenhouse gases accumulating in our congested atmosphere, that ultimately prove the final agent of human destruction. We need to pay closer attention to the air we take so much for granted, mark what is burning and melting, look to the heavens, listen to the winds, and heed the rising waves—before it is too late.

TIMELINE

1620 Johann Baptista van Helmont (1579–1644) coins the term "gas."

1754 Scottish chemist Joseph Black (1728–99) heats calcium carbonate to form calcium oxide and a gas (carbon dioxide) that he calls "fixed air."

1771 Joseph Priestley (1733–1804) isolates oxygen, which he at first thinks to be "phlogisticated nitrous air" (nitrous oxide), but after further study in 1775 he will call "dephlogisticated air."

1773 Priestley isolates the anaesthetic qualities of nitrous oxide.

1774 Carl Wilhelm Scheele (1742–86), a Swedish chemist, discovers chlorine.

1775 Antoine Laurent Lavoisier (1743–94) after meeting with Priestley publishes a paper in which he claims that air is a mixture of gases and that just one component which he calls oxygen (Priestly's "dephlogisticated air") is fundamental to life itself.

1786 Scheele dies after inhaling HCN, which he had just discovered.

1794 Lavoisier, "the father of chemistry," is guillotined in the French Revolution.

1812 Sir Humphry Davy (1778–1829), a British chemist, synthesizes phosgene.

1846 American dentist William Thomas Green Morton uses nitrous oxide for painless tooth extraction upon patient Eben Frost; Oliver Wendell Holmes Sr. later proposes naming the procedure anesthesia.

1847 Lewis P. Haslett files the first known U.S. patent for a protective gas mask.

1848 John Stenhouse, a Scotch chemist and inventor, synthesizes chloropicrin.

1874 The first international effort to control chemical and biological weapons (the International Declaration Concerning the Laws and Customs of War) is signed in Brussels.

1886 Viktor Meyer (1848–97) fully identifies dichloroethylsulfide (commonly known as mustard agent).

1899 The Hague Peace Conference banning the use of poisons is ratified by the United States. One provision states: "The contracting Powers agree to abstain from the use of projectiles the sole object of which is the diffusion of asphyxiating gasses."

1902 Novelist Emile Zola dies from accidental carbon monoxide poisoning in Paris.

1907 The 1907 Second Hague Peace Conference again bans the use of poisons in warfare.

1915	Led by master chemist Fritz Haber (1868–1934), the German Army carries out the world's first deadly chemical attack using poison gas (chlorine) at Ypres.
1916	The German Army starts using diphosgene in combat, while the French begin using hydrogen cyanide and cyanogen chloride gas.
1918	World War I ends. About 1 million of its estimated 26 million casualties were caused by poison gas. Of America's total of 272,000 casualties, over 72,000 (about one-fourth) involved gas. Many tout chemical warfare as the warfare of the future.
1919	Britain's Winston Churchill authorizes using poison gas against "uncivilized tribes" in Iraq.
1924	The world's first gas chamber execution is carried out in Nevada Srate Prison on Gee Jon, a Chinese prisoner convicted of murder.
1925	Twenty-eight nations, including the United States, sign the Geneva Protocol, condemning chemical and biological warfare. But the U.S. Senate refuses to ratify it.
1935	Italy's forces under Benito Mussolini use mustard gas against Ethiopian troops and civilians.
1936	Dr. Gerhard Schrader (1903–90) in Germany's IG Farben laboratory in Leverkusen, prepares the first tabun nerve agent (GA).
1938	German scientists discover the nerve agent sarin (GB).
1939	Imperial Japanese forces use mustard gas and lewisite against the Chinese.
1940	Nazis start gassing prisoners as part of their "eurhanasia" program, using carbon monoxide.
1940	Imperial Japan conducts poison gas experiments and biological warfare experiments on human subjects at Unit 731. One experiment tests mustard gas on 16 Chinese prisoners.
1941	Germans start gassing prisoners in concentration camps, first using carbon monoxide and later Zyklon-B. The latter is initiated on Soviet prisoners of war at Auschwitz concentration camp in Poland and later used ro exterminate Jews.
1941–45	President Franklin D. Roosevelt establishes a no-first-use policy for chemical weapons early in the war that he later repeats in the following official statement: "We shall under no circumstances resort to the use of such [chemical] weapons unless they are first used by our enemies."
1942–45	The U.S. Chemical Warfare Service conducts mustard gas experiments on approximately 4,000 U.S. servicemen. Many tests use pacifist Seventh Day Adventists who elected to become human guinea pigs rather than serve on active war duty.
1943	A United States Liberty Ship, *SS John Harvey*, is bombed by Nazi air attack in Bari, Italy, unleashing its secret cargo of mustard gas that kills more than 1,000 sailors and Italian civilians. The mishap reveals that Allied forces have stockpiled chemical weapons for possible use against Germany, thereby showing that poison gas may again become used in war. But the

threat does not materialize, and neither side resorts to using lethal chemical weapons against combatants.

1945 The liberation of Nazi death camps reveals the horrors of the gas chamber.

1949 American chemist Willard Frank Libby (1908–1980) discovers the empirical radiocarbon dating method that can determine the approximate age of carbonaceous materials that are up to about 60,000 years old.

1950s–90s Hans Suess (1909–1993), a Vienna-born physical chemist working for the U.S. Geological Survey, becomes the first scientist to apply hydrocarbon dating to greenhouse science.

1953 As part of an experiment, the U.S. military releases clouds of zinc cadmium sulfide gas over several cities in Canada and the United States.

1953 British soldier Ronald Maddison dies as a result of a sarin nerve agent experiment at England's Porton Down.

1956 Regular production of sarin nerve agent ceases in the United States.

1960 High-profile prisoner Caryl Chessman is executed in California's San Quentin Prison gas chamber.

1967 CIA and Department of Defense implement Project MKNAOMI, designed to maintain, stockpile and test biological and chemical weapons.

1968 Near Dugway Proving Ground in Utah, approximately 6,400 sheep are found dead after the accidental release of deadly VX nerve gas from a military plane. The incident sets off an international uproar over chemical warfare.

1979 New York Yankees catcher Thurman Munson dies of accidental cyanide/carbon monoxide poisoning in an airplane mishap.

1984 Deadly release of poison gas in Bhopal, India, kills over 3,000 local residents near Union Carbide plant.

1984 Carbon dioxide gas in Lake Monoun in northwestern Cameroon kills 37 persons.

1986 Carbon dioxide gas in Lake Nyos in northwestern Cameroon kills 1,700 people.

1988 Iraqi dictator Saddam Hussein uses chemical weapons against Kurds in Halabja, Iraq, killing more than 5,000 civilians.

1991 At end of Gulf War, U.S. Army destroys a huge ammunition bunker complex at Khamisiyah in southern Iraq, inadvertently releasing high levels of nerve agents near thousands of unprotected U.S. troops, resulting in "Gulf War illness."

1991 UN Security Council adopts Resolution 687, establishing the term "weapons of mass destruction," setting forth terms of the Gulf War ceasefire, and banning Iraq from possessing chemical, biological or nuclear weapons or ballistic missiles with a range of more than 150 km. UN creates a special weapons inspection team called UNSCOM to monitor Iraq's compliance.

1993 Al Qaeda truck bomb damages World Trade Center in New York City, but a load of deadly cyanide fails to cause additional casualties.

1993 Chemical Weapons Convention is signed in Paris by the United States, Russia, and 128 other countries, prohibiting the development, production, stockpiling, and use of chemical weapons. The treaty also regulates private chemical companies. But the U.S. Senate delays ratification.

1994 U.S. Senate reports that for at least 50 years the Department of Defense has used hundreds of thousands of military personnel in hazardous human experiments. Some of the materials tested included mustard and nerve gas, ionizing radiation, psychochemicals, and drugs.

1994 Members of a Japanese religious cult, Aum Shinrikyō, release nerve agent sarin on Japanese civilians, killing 7 and injuring 500.

1995 Aum terrorists release sarin in crowded Tokyo subway, killing 12 and causing more than 5,500 injuries.

1997 Chemical Weapons Convention becomes effective.

2002 Chechen hostage incident at a Moscow theater is crushed after Russian troops stage a deadly gas attack using fentanyl.

2003 U.S. forces invade Iraq, claiming to look for weapons of mass destruction and find none.

2005 Nine persons die and at least at least 234 people are hospitalized after a train wreck accidentally releases chlorine gas in Graniteville, South Carolina.

2007 Another mysterious stink in New York City.

Al Qaeda launches chlorine gas terror attacks in Iraq.

The deadline for destruction of chemical weapons stockpiles passes without full compliance by the two biggest stockpilers, the United States and Russia.

Glossary

Adamsite (lo-Chloro-5): a non-lethal gas used as a harassment agent in World War I.

Aerosols: a cloud of micron-size liquid droplets or solid particles dispersed by pressurized gases.

Agent Orange: a toxic defoliant containing dioxin that U.S. military air forces dropped in huge quantities on Southeast Asia during the Vietnam war, causing extensive damage to health and the environment.

Alchemy: the medieval science that sought to convert base metals into gold, cure disease, and achieve everlasting youth.

Amiton: a type of nerve agent.

Arsenic: a type of classical poison.

Asphyxia: (from the ancient Greek meaning without pulse, heartbeat) a physical condition of severely deficient supply of oxygen to the body. Unless effective remedial action is taken, asphyxiation very rapidly leads to unconsciousness, brain damage, and death.

Asphyxiating agent: an agent causing choking or suffocating.

Atropine: a tropane alkaloid extracted from the plant family Solanaceae; atropine is best known for its use in resuscitation of persons exposed to nerve agents.

Binary weapon: a chemical weapon consisting of two substances that are harmless when used alone, but when combined just before deployment they form a toxic nerve agent. Binary weapons offered safety advantages for manufacture, storage and transport.

Blister agent (vesicant): a toxic chemical agent such as mustard gas that burns the skin, producing water blisters which heal slowly and may become infected; it can damage the eyes, blood cells and respiratory tract.

Blood agents: chemical agents such as hydrogen cyanide that are absorbed into the blood by breathing or through the skin; they can cause the body's vital organs to cease functioning, resulting in death.

BZ (QNB or Quinuclidinebenzillate): an incapacitating chemical agent developed by the U.S. military in the 1950s; it affects the nervous system, causing hallucinations.

Carbon dioxide (CO_2): a chemical compound composed of 2 oxygen atoms covalently bonded to a single carbon atom; carbon dioxide is a colorless, odorless, incombustible gas formed by decomposition of organic materials as well as respiration and combustion.

It becomes a lethal gas at high concentrations. Carbon dioxide is considered the most important greenhouse gas. In March 2009, tests revealed its level in the Earth's atmosphere was 387 ppm (parts per million), and many environmental scientists warned that the level must be reduced to 350 ppm to be safe.

Carbon monoxide (CO): a chemical compound composed of one carbon atom covalently bonded to one oxygen atom; a lethal gas, known as the silent killer.

Chemical agent: a chemical substance that can cause physiological changes in humans; used in chemical warfare.

Chemical weapons (CW): chemical agents used in chemical warfare. Such weapons include many chemical agents that are designed to harass, incapacitate, injure, or kill an enemy. The large-scale and systematic industrial development and use of chemical weapons began in World War I.

Chlorine (Cl): the chemical element with atomic number 17. In its common elemental form, under standard conditions, chlorine is a pale green gas about 2.5 times as dense as air. Its sharp, suffocating odor is detectable in concentrations as low as 3.5 ppm. At high concentrations, chlorine is choking and poisonous, making it one of the first poison gases deployed in World War I. Chlorine also has many legitimate industrial uses.

Choking agents: attack the respiratory tract, causing the lungs to fill with fluid. They can cause the victim to drown; survivors often suffer chronic breathing problems. The most commonly used lethal choking agents used in warfare have included phosgene, diphosgene, and chloropicrin.

CN (Chloracetophenone): a non-persistent irritant chemical agent commonly used by law enforcement as a type of gas for harassment purposes, CN can also prove lethal to certain human beings in enclosed spaces.

Compound: a pure substance composed of two or more elements.

Convulsants: chemical agents that make muscles contract causing convulsions.

CS gas: tear gas that is used for riot and crowd control.

Curie (Ci): the standard measurement signifying a unit of radioactivity, equal to the amount of a radioactive isotope that decays at the rate of 3.7×10^{10} disintegrations per second.

Cyanide chloride (CNCl): a lethal chemical compound that blocks oxygen intake in the blood.

Cyanosis: bluish skin color due to insufficient oxygen caused by ingestion of cyanide.

Cyclohexyl methylphosphjonogluoridate (GF): a member of the organosphosphorus compound family, this lethal nerve gas is dispersed through the skin or inhalation.

Cyclosarin (cyclohexyl methylphosphonofluoridate or GF): a member of the organosphosphorus compound family, this deadly nerve agent was not considered a significant chemical warfare agent until U.S. forces encountered it in Iraq during Operation Desert Shield.

Defoliant: a toxic chemical substance that causes plants to shed leaves. The best known example is Agent Orange.

Dephlogisticated air: early name for oxygen.

Dephlogisticated nitrous air: early name for nitrous oxide.

Dioxin: (TCDD—2,3,7,8-tetrachlorodibenzoparadioxin): this deadly industrial pollutant is considered one of the most persistent and dangerous poisons because of its long-term effects on the food chain.

Dyspnea: sensation of difficulty in breathing.

Euthanasia: intentional killing to relieve suffering; mercy killing.

Fixed air: early name for carbon dioxide, coined by eighteenth-century chemist Joseph Black.

Fluorine: a poisonous, pale, yellowish/brown gas, used in nuclear weapons manufacture as well as in air conditioners, dentistry, and for other industrial purposes.

Fumarole: a steam or gas vent found in a volcanic area.

Gas: a state of matter that is neither a solid nor a liquid at ordinary temperatures and has neither independent shape nor volume but tends to expand indefinitely.

Gas chamber: a sealed enclosure into which gases can be pumped and contained, used for testing, training or execution purposes. The first lethal gas chamber execution occurred in 1924.

Gas chromatograph-mass spectrometer (GC/MS): a device used to identify unknown chemical compounds.

GA (tabun or phosphoramidocyanidic acid, dimethyl, ethyl es-ter): the first lethal nerve gas, discovered by German scientists in 1936 and stockpiled as a chemical weapon.

GB (Sarin phosphonoflouridic acid, methyl, 1-methylethyl ester): a colorless, odorless lethal nerve agent, discovered by German scientists in 1939.

GD (Soman—phosphonofluoridic acid, methyl, 1,2,2-trimethyl-propyl ester [R-(R*, R*)]): a lethal nerve agent discovered by German scientists in 1944.

Global warming: a rising average temperature of the Earth's surface and lower atmosphere caused by greenhouse gases.

Greenhouse effect: warming of the surface and lower atmosphere of the Earth caused by an accumulation of certain gases.

Greenhouse gases: gases that trap heat in the atmosphere. Examples include carbon dioxide, methane, nitrous oxide, and fluorinated gases.

HD (mustard gas, mustard sulphur, ethane,1,1'-thiobis[2-chloro-]): a type of blister agent war gas.

Herbicide: a toxic chemical agent used to kill plants and crops.

Hydrogen cyanide (HCN): a chemical compound that blocks the blood's oxygen intake; combined with water it forms hydrocyanic acid or Prussic acid. Used in execution gas chambers by the United States and Nazi Germany.

Hypoxia: a pathological condition wherein the body is deprived of oxygen.

Insecticides: toxic chemicals used to kill insects; some of these substances have a chemical structure similar to that found in chemical weapons.

Lacrimator: a material that irritates the eyes, nose and mucous membranes and causes tearing; this type of chemical weapon made soldiers take off their gas masks, thereby making them more susceptible to other, lethal chemical agents.

LD 50: the dose of a poison sufficient to cause death in 50 percent of the test animals; it is measured in milligrams per kilogram of body weight.

Lethal chamber: a gas chamber imagined by Utopians as being used for euthanasia; by the late nineteenth and early twentieth century such devices were beginning to be used to kill large numbers of animals and human beings.

Lewisite (2-chloroethenyldichloroarsine, $C_2H_2AsCl_3$): an oily, yellow or brown liquid compound containing arsenic that smells like geraniums. Used since WWI as a deadly chemical weapon, lewisite acts as a vesicant (blister agent) and lung irritant; it was often used with mustard.

LSD (Lysergic acid diethylamide): a psychedelic drug, this hallucinogen was developed in the 1950s by the U.S. military as an incapacitating agent and an interrogation tool; it became an illicit recreational drug in the 1960s when it was popularized by Dr. Timothy Leary.

Marsh gas: swamp gas, methane.

Methane (CH_4): an odorless, flammable greenhouse gas.

Mustard gas: a highly toxic chemical agent that is used in chemical warfare to cause skin blisters and lung burns; this colorless and odorless liquid can kill slowly. It is a systemic poison that damages the body and is a carcinogen. Due to its extremely persistent and pernicious effects, it has been the most pervasive modern war gas.

Nerve agents: these very toxic and potentially lethal chemical agents attack the nervous system by inhibiting the enzyme that aids the transmission of nerve impulses. Common nerve agents include tabun, sarin, soman and VX. G-series nerve agents are non-persistent and cause death by inhalation; V-series nerve agents are persistent and are absorbed through skin.

Osmium tetroxide (OsO_4): a highly poisonous, volatile compound linked to an alleged al Qaeda bombing plot on the London Underground in 2004.

Pesticides: chemical substances for killing rats, gophers and other pests; some of these products resemble nerve agents.

Phlogisticated air: early name for nitrogen.

Phlogiston: antiquated eighteenth-century theory describing the flammable principle common to all fuels and oxidized metals thought to be released during combustion and oxidation.

Phosgene (carbonyl chloride or COCl): a colorless poisonous choking gas used in warfare and industry.

Phosphine (PH_3): the common name for phosphorus hydride, a colorless and flammable gas that smells like garlic or rotting fish.

Picocurie (pci): this measurement unit stands for one trillionth of a curie.

Plinian column: a buoyant column of pumice, ash, and hot gas that is ejected explosively from the volcanic vent to rise tens of thousands of feet into the atmosphere.

Precursor chemical materials: substances which, following chemical processing and combinations, form building blocks for the construction of chemical weapons as defined by the Chemical Weapons Convention.

Pyroclastic flow: a mass of hot pumice and ash, buoyed by hot gas, which crosses the ground at high speed during a volcanic eruption.

Radon (Rn): a colorless, odorless, naturally occurring, radioactive, inert, gaseous element formed by radioactive decay of radium atoms. Radon is a leading cause of lung cancer.

Riot control Agent: a chemical substance used for crowd control, examples of this harassment chemical agent include pepper spray or tear gas.

Sarin (GB or isopropyl methylphosonofluoridate): a colorless, odorless volatile nerve gas that was first synthesized at IG Farben, Germany, in 1938. It kills its victims mainly through inhalation.

Smoke: the gaseous products of burning materials especially of organic origin made visible by the presence of small particles of carbon.

Soman (GD or pinoacolyl methylphosphonofluoridate): fastest-killing nerve gas, produced in 1944 for the first time at IG Farben; kills both through inhalation and skin contact.

Sulfur dioxide (SO_2): a toxic chemical compound produced by volcanoes and various industrial processes.

Tabun (GA or O-ethyl dimethylamidophosphorylcyanide): the first nerve gas, developed in 1936 at IG Farben.

Tear gas (CN—cloroacetophenone; CR—dibenz (b,f)-1,4-oxaze-pine; CS—orthochlorobe-nzylide-nemaonitrile): a toxic substance that causes pain in the eyes, flow of tears, and difficulty in keeping eyes open; this non-lethal chemical agent is used for crowd and riot control.

Vapor: an air dispersion of molecules of a substance that is normally a liquid or solid at standard temperature and pressure.

V-agents: a group of lethal nerve agents.

Vesicants: chemical agents that induce blistering.

VX (Phosphonothioic acid, methyl-,S-[2-[bis(1-methylethyl)ami-no]ethyl] O-ethyl ester): an odorless, colorless liquid that disrupts the stimulus from nerve to muscle in the human body, causing convulsions, paralysis and death. Discovered in the United Kingdom in 1952, it was mass-produced for military purposes in the United States during the 1960s. The substance can persist for several weeks on terrain, equipment or material; it is mainly taken up through skin but also through inhalation as a gas or aerosol. It attracted international attention as a result of the Dugway sheep kill in 1968.

Zyklon-B: a very lethal form of hydrogen cyanide used in gas chamber executions, it was manufactured by German, American and British chemical companies.

Appendix

Organizations That Can Help

American Lung Association
Home page: www.lungusa.org
Phone: 202-785-3355 Washington, DC; 212-315-8700 NY

"When you can't breath, nothing else matters"
The American Lung Association (ALA) is the oldest voluntary health organization in the United States. ALA is dedicated to fighting lung disease in all forms, with a special emphasis on environmental health. For the past decade, ALA has partnered with the US Environmental Protection Agency to provide education on radon. ALA and its affiliates offer various public education and outreach programs and materials to promote radon testing and remediation.

Amnesty International
Home page: www.amnestyusa.org
Phone: 212-807-8400 NYC

Founded in London in 1961, Amnesty International is a Nobel Prize-winning grassroots activist organization with over 1.8 million members worldwide. Amnesty International undertakes research and action focused on preventing and ending grave abuses of the rights to physical and mental integrity, freedom of conscience and expression, and freedom from discrimination, within the context of its work to promote all human rights. Amnesty International USA (AIUSA) is the U.S. Section of Amnesty International.

Chemical Weapons Working Group
Home page: www.cwwg.org
Phone: 859-986-0868 Berea, KY

The Chemical Weapons Working Group is an international coalition of citizens living near chemical weapons storage sites in the United States, the Pacific, and Russia who are most affected by the disposal of these munitions. The CWWG's mission is to oppose incineration of chemical weapons as an unsafe disposal method and to work with all appropriate decision-making bodies to ensure the safe disposal of these munitions and other chemical warfare and toxic material.

The organization's mission is based on a primary concern for the preservation and protection of the health and safety of all citizens and the environment in which they live.

Greenpeace
Home page: www.greenpeace.org/usa
Phone: 202-462-1177 Washington, DC

Greenpeace is the leading international, independent campaigning organization that uses direct peaceful action and creative communication to expose global environmental problems and to promote solutions that are essential to a green and progressive future.

Human Rights Watch
Home page: www.hrw.org
Phone: 212-290-4700 NYC

Human Rights Watch is an independent, nongovernmental organization, dedicated to protecting the human rights of people around the world.

Organisation for the Prohibition of Chemical Weapons
Home page: www.opcw.org
Phone: +31 70 416 3300 The Hague, the Netherlands

This organization is charged with enforcing the provisions of the Chemical Weapons Convention.

Sierra Club
Home page: www.sierraclub.org
Phone: 415-977-5500 San Francisco

The Sierra Club is the oldest and largest environmental organization in the United States.

Students for Bhopal
Home page: www.studentsforbhopal.org
Phone: 415-981-6205 ext. 355 San Francisco

Students for Bhopal is the international student campaign to hold Dow accountable for Bhopal, and its other toxic legacies around the world.

U.S. Centers for Disease Control & Prevention
Home page: www.cdc.gov
Phone: 404-639-3311 Atlanta, GA

This is the federal agency charged with promoting health and quality of life by preventing and controlling disease, injury disability. One of its missions is to provide independent oversight to the U.S. chemical weapons elimination program and serve as an important element in ensuring the safe destruction of chemical warfare material for protection of public health.

U.S. Chemical Safety & Hazard Investigation Board
Home page: www.chemsafety.gov
Phone: 202-261-7600 Washington, DC

This is an independent federal agency investigating chemical accidents to protect workers, the public, and the environment.

U.S. Environmental Protection Agency
Home page: www.epa.gov
Phone: 202-272-0167 Washington, DC

The stated mission of the U.S. Environmental Protection Agency is to protect human health and the environment.

NOTES

NEWSPAPER ABBREVIATIONS

ADS	*Arizona Daily Star*
AR	*Arizona Republic*
AZ	*Al Zaman* (London)
BG	*Bedford* (PA) *Gazette*
BS	*Baltimore Sun*
CCDA	*Carson City Daily Appeal*
CD	*China Daily*
CDM	*Canandaigua Daily Messenger*
CG	*Charleston* (WVA) *Gazette*
CSM	*Christian Science Monitor*
DA	*Dearborne Independent*
DP	*Denver Post*
ECT	*Elmira* (NY) *Chronicle-Telegram*
FB	*Fresno Bee*
G	*The Guardian* (UK)
GDG	*Gastonia* (NC) *Daily Gazette*
LADJ	*Los Angeles Daily Journal*
LAHE	*Los Angeles Herald Examiner*
LAT	*Los Angeles Times*
LT	*London Times* (UK)
NSJ	*Nevada State Journal*
NYEW	*NY Evening World*
NYHT	*NY Herald Tribune*
NYT	*New York Times*
OT	*Oakland Tribune*
PI	*Philadelphia Inquirer*
PR	*Pinoche Record*
PPG	*Pittsburgh Post-Gazette*
RGJ	*Reno Gazette Journal*
REG	*Reno Evening Gazette*
RMN	*Rocky Mountain News*
SB	*Sacramento Bee*

SFCP	*San Francisco Call & Post*
SFC	*San Francisco Chronicle*
SFE	*San Francisco Examiner*
SH	*Sunday Herald* (UK)
SJM	*San Jose Mercury*
SLT	*Salt Lake Tribune*
TDT	*Tonopah Daily Times*
USAT	*USA Today*
WP	*Washington Post*
YC	*Young China*

Chapter 1: Agents of the Gods

1. Diodorus Siculus was a contemporary of Julius Caesar who wrote a general history in 40 books. The story of the oracular goatherd comes from Book 16.26 of his *The Library of History*, as translated by Charles L. Sherman in Vol. VII of the Loeb Classical Library edition, 1951, 310–11.

2. "Divine afflatus" is discussed in Preble & Laury, "Plastic Cement: The Ten Cent Hallucinogen," 271–72.

3. The Temple of Apollo was positioned directed atop the cavern with its *adyton* (inner sanctum) located directly above the fissure. The spring of Kassoris ran above-ground near the site and plunged underground, reappearing within the *adyton*. It was from this gaseous part of the spring that Pythia drank in preparation for her mantic sessions. Connelly, *Portrait of a Priestess*, 76–77.

4. Barry S. Strauss, *The Battle of Salamis: The Naval Encounter that Saved Greece—and Western Civilization* (New York: Simon & Schuster, 2004): 63.

5. Eloise Hart, "The Delphic Oracle," *Sunrise Magazine* (October/November 1985).

6. H. W. Parke, *A History of the Delphic Oracle* (London: Basil Blackwell, 1939).

7. Fonterose, *Didyma: Apollo's Oracle, Cult, and Companions*, 353.

8. de Boer, Hale and Chanton, "New Evidence for the Geological Origins of the Ancient Delphic Oracle (Greece)," 707–10; Spiller, Hale and de Boer, "The Delphic Oracle: A Multidisciplinary Defense of the Gaseous Vent Theory," 189–96; Gugliotta, "Faults Suggest a High Calling for Delphi Priestesses."

9. Negria and Leucc, "Geophysical Investigation of the Temple of Apollo (Hierapolis, Turkey)."

10. Ibid.

11. Partington, *Greek Fire*; Cobb & Goldwhite, *Creations of Fire: Chemistry's Lively History from Alchemy to the Atomic Age*, 61–62.

Chapter 2: Plucky Pioneers

1. Cobb & Goldwhite, *Creations of Fire: Chemistry's Lively History from Alchemy to the Atomic Age*, 99.

2. See Partington, *A Short History of Chemistry*, 23; Brock, *The Chemical Tree: A History of Chemistry*, 3.

3. The transition from alchemy to chemistry is recounted in Partington, *A Short History of Chemistry,* 41–44.

4. Helmont, *Ortus Medicinae*; Cobb & Goldwhite, *Creations of Fire*, 110–114; Partington, *A Short History of Chemistry,* 46.

5. Helmont, *Ortus Medicinae.*

6. Partington, *A Short History of Chemistry,* 48–51.

7. Almqvist, *History of Industrial Gases*, 3.

8. The quotation is from King Lear, act 5, scene 3.

9. John Joachim Becher, ca. 1650, quoted in Cobb & Goldwhite, frontispiece.

10. Crosland, *Instruments and Experimentation in the History of Chemistry,* 94.

11. Scheele, *Chemical Treatise on Air and Fire.*

12. Ibid.

13. Scheele, *Chemical Treatise on Air and Fire*; Tilden, *Famous Chemists*, 58.

14. Robinson, *The Story of Medicine*, 355.

CHAPTER 3: VOLCANOES: CARBON DIOXIDE, SULFUR DIOXIDE, HYDROGEN SULFIDE

1. This account is based on Ward-Perkins & Claridge, *Pompei, A. D.* and Butterworth & Lawrence, *Pompeii.*

2. Pliny the Younger, letter to Tacitus, quoted in http://faculty.cua.edu/pennington/Naples/LectureOne/PlinyLetters.htm#Pliny3. See also Beard, *The Fires of Vesuvius.*

3. Bosch, "Scientists Solve Mystery of Volcano's 'Natural Deaths.' "

4. Pliny the Younger, letter to Tacitus, quoted in http://faculty.cua.edu/pennington/Naples/LectureOne/PlinyLetters.htm#Pliny3.

5. See Jashemski and Meyer, eds., *The Natural History of Pompeii.*

6. Twain, *Mark Twain in Hawaii, Roughing It in the Sandwich Islands*, 77.

7. For daily monitoring data on Kilauea, see U.S. Geological Survey, http://volcano.wr.usgs.gov/kilaueastatus.php.

8. See U.S. Geological Survey, Volcano Hazards Program, http://volcanoes.usgs.gov/.

9. See U.S. Department of Health and Human Services, Public Health Statement for Sulfur Dioxide, http://www.atsdr.cdc.gov/toxprofiles/phs116.html.

10. For USGS information about Kilauea's sufur dioxide, see http://volcanoes.usgs.gov/hazards/gas/volgaspollution.php.

11. Gerlach, McGee, Elias, Sutton and Doukas, "Carbon Dioxide Emission Rate of Kilauea Volcano."

12. U.S. Geological Survey, Invisible CO2 Gas Killing Trees at Mammoth Mountain, California," *http://pubs.usgs.gov/fs/fs172-96/fs172-96.pdf* .

13. See USGS, "Volcanic Gases and their Effects," available at http://volcanoes.usgs.gov/hazards/gas/index.php.

14. Carbon dioxide emissions: Sieh & LeVay, *The Earth in Turmoil: Earthquakes, Volcanoes, and Their Impact on Humankind*, 151.

15. For information about hydrogen fluoride, see U.S. Centers for Disease Control, Public Health Statement, http://www.atsdr.cdc.gov/toxprofiles/tp11-c1.pdf.

16. For information about hydrogen sulfide, see U.S. Centers for Disease Control, Public Health Statement, http://www.atsdr.cdc.gov/toxprofiles/phs114.html.

17. U.S. Geological Survey, "Volcanic Gases and their Effects," http://volcanoes.usgs.gov/hazards/gas/index.php.

18. de Boer, Zeilinga and Sanders tell the story of nine such epic volcanic events, explaining the related geology for the general reader and exploring the myriad ways in which the earth's volcanism has affected human history. See de Boer, Zeilinga and Sanders, *Volcanoes in Human History.*

19. See Winchester, *Krakatoa: The Day the World Exploded, August 27, 1883.*

20. Mason, Pyle & Oppenheimer, "The Size and Frequency of the Largest Explosive Eruptions on Earth"; Supervolcanoes, BBC2, 3 February 2000, http://www.bbc.co.uk/science/horizon/1999/supervolcanoes_script.shtml.

CHAPTER 4: NITROUS OXIDE: "THIS WONDER-WORKING GAS OF DELIGHT!"

1. See Fullmer, "Young Humphry Davy: The Making of an Experimental Chemist."

2. "I soon learnt": Cottle, *Reminiscences of Samuel Taylor Coleridge and Robert Southey.*

3. Joseph Priestley, *Experiments and Observations on Different Kinds of Air* (London, 1775).

4. "Respirable, and capable" and "Having accidentally cut": quoted in W. D. A. Smith, "A History of Nitrous Oxide and Oxygen Anaesthesia, Part I: Joseph Priestley and Humphry Davy," 793.

5. April 1799 quote: Davy, "Letter from Mr. H. Davy," in *Nicholson's Journal*, 3, 55; and Davy, *Researches, Chemical and Philosophyical, chiefly concerning nitrous oxide, or dephlogisticated nitrous air, and its respiration*, 456.

6. Humphry Davy, *Researches*, 457–58.

7. For "a sense of exhilaration": ibid., 487.

8. "I felt a sense of tangible extension": ibid., 488–89.

9. Cottle, *Reminiscences of Samuel Taylor Coleridge and Robert Southey.*

10. Cottle, *Reminiscences of Samuel Taylor Coleridge and Robert Southey.*

11. Davy, *Researches*, 457–58.

12. See Buxton, "Those Who Worked in the Dawn of Anaesthesia."

13. "The effect of the gas": Cohen & Dripps, in Goodman and Gilman, *The Pharmacological Basis of Therapeutics, 4th ed.*, 43.

14. "It is the greatest discovery": Smith & Hirsch, "Gardner Quincy Colton" Pioneer of Nitrous Oxide Anaesthesia."

15. See Menczer and Jacobsohn, "Dr. Horace Wells, the Discoverer of Anaesthesia."

16. See American Academy of Pediatric Dentistry, *Clinical Guideline on Appropriate Use of Nitrous Oxide for Pediatric Dental Patients.*

17. Leake, "Valerius Cordus and the Discovery of Ether."

18. See Gravenstein, "Paracelsus and His Contributions to Anesthesia."

19. For more of ether's history, see Fenster, *Ether Day: The Strange Tale of America's Greatest Medical Discovery and the Haunted Men Who Made It.*

20. Vandam, "Imagining in Time."

21. For Morton, see Johnson, *The Ghost Map: The Story of London's Most Terrifying Epidemic—and How It Changed Science, Cities, and the Modern World*, 63–64.

22. Holmes: This letter is reproduced at http://www.general-anaesthesia.com/misc/index.html

23. Fenster, *Ether Day: The Strange Tale of America's Greatest Medical Discovery and the Haunted Men Who Made It.*

24. See Simpson, "On a New Anaesthetic Agent, More Efficient than Sulphuric Ether."

25. Menczer and Jacobsohn, "Dr. Horace Wells, the Discoverer of General Anesthesia."

26. On chloroform, see Squibb, "Anaesthetics," 389.

27. About Davy and others who nearly died from experiments, see Cobb & Goldwhite, *Creations of Fire*, 190.

Chapter 5: First World War

1. History of chlorine, see Christman, "The History of Chlorine," 66–67; Johnson, *The Ghost Map.*

2. Early use of gas at the front, see Hammond, *Poison Gas*, 9.

3. Fritz Haber quoted in Harris & Paxman, *A Higher Form of Killing.*

4. Quoted in Seagrave, *Yellow Rain*, 42.

5. See Hossack, "The First Gas Attack."

6. "We heard them say it was gas": Quoted in http://www.spartacus.schoolnet.co.uk/FWWchlorine.htm

7. Ellis, *Eye-Deep in Hell: Trench Warfare in World War I*, 66.

8. Quoted in http://www.sparracus.schoolnet.co.uk/FWWchlorine.htm

9. Rev. O. S. Watkins, Ypres, Belgium, April 1915, quoted in Fries and West, *Chemical Warfare*, 13.

10. On Clara Haber: see Goran, The Story of Frirz Haber; Haber, *The Poisonous Cloud: Chemical Warfare in the First World War.*

11. See Smart, *History of Chemical and Biological Warfare: An American Perspective.*

12. Foulkes, *"Gas!" The Story of the Special Brigade.*

13. Tommies never knew what hit them. Tucker, *War of Nerves*, 18.

14. 18 times more lethal: Fries and West, *Chemical Warfare*, 126–27.

15. "White efflorescence around the mouth . . ." PRO, WO 142/101, quoted in Harris and Paxman, *A Higher Form of Killing*, 20.

16. "Lying huddled together." Foulkes, *"Gas!" The Story of the Special Brigade*, 127.

17. "It floated over Vimy . . ." Foulkes, "*Gas!*," 212.

18. A new kind of mortar: Prentiss, *Chemicals in War*, 52–53.

19. *Gaswerfer 1918:* Harris & Paxman, *A Higher Form of Killing*, 35.

20. US was turning out phosgene. Fries & West, *Chemical Warfare*, 127–30.

21. July 12 attack. Harris & Paxman, *A Higher Form of Killing*, 26; Croddy, *Chemical and Biological Warfare: A Comprehensive Survey for the Concerned Citizen.*

22. "Blister which suppurates . . . " Duchovic & Vilensky, "Mustard Gas: Its Pre-World War I History."

23. Meyer's rabbit experiments . . . V. Meyer, Ber. Deut. Chem. Ges., 12 (1886): 3259–66; J. K. Senior, *Armed Forces Chemical Journal*, 12 (1958): 12.

24. Germany's dye industry already had precursor chemicals: Prentiss, *Chemicals in War*, 625.

25. Origins of LOST: Vilensky & Sinish, "Dew of Death"; Croddy, *Chemical and Biological Warfare: A Comprehensive Survey for the Concerned Citizen.*

26. Vilensky & Sinish, "Dew of Death"; Croddy.

27. Mustard's winning formula: Fries & West, *Chemical Warfare,* chapter IX.

28. Fries & West, 151.

29. Capacity of U.S. mustard factories: Crowell, 403–4. American newspapers trumpeted the power of U.S. factories to mass produce mustard gas. See, e. g., "Mustard Gas Warfare," *NYT,* 7 July 1918, 52.

30. " . . . they know they are going to choke." Vera Brittain. See also "Fatal Exposure to Mustard Gas."

31. " . . . fooling around with simulated death . . . " Ty Cobb, quoted in Gurtowski, "Remembering Baseball Hall of Famers Who Served in the Chemical Corps," 52.

32. "Ty, I got a good dose of the stuff." ibid., 53–54.

33. MacArthur: Manchester, *American Caesar,* 89–91, 104.

34. Injuries at Avonmouth: Harris & Paxman, 30.

35. Farrow, *Gas Warfare.*

36. Winford Lewis lab tests. Vilensky & Sinish, "Dew of Death,"54–55; Vilensky, *Dew of Death,* 21. See also "Death of an Inventor," *Time,* 1 Feb. 1943.

37. Vilensky, *Dew of Death,* 32–33.

38. Vilensky, *Dew of Death,* 31.

39. AUES casualty rate compared to Edgewood's: Pringle, *Chemical and Biological Warfare: The Cruelest Weapons,* 24.

40. Pringle, "Profiles: Mr. President-I: James Bryant Conant," 24.

41. "Lewisite shock" and other effects: Pechura and Rall, *Veterans at Risk: The Health Effects of Mustard Gas and Lewisite,* 164–65.

42. Willoughby plant . . . "great American gas which could win the war." Brophy, Miles & Cochrane, *The Chemical Warfare Service: From Laboratory to Field,* 67; Hershberg, *James B. Conant: Harvard to Hiroshima and the Making of the Nuclear Age,* 47.

43. Plans to annihilate Berlin: Lt. Col. Augustin M. Prentiss of the Chemical Warfare Service wrote in his book, *Chemicals in War* (1937), considered the most thorough military treatise on chemical warfare: "Our offensive in 1919, in my opinion, would have been a walk to Berlin, due to chemical warfare. The campaign of 1919 would have been largely a chemical war." Quoted in Vilensky & Sinish, "Dew of Death," 54–60. *The New York Times* reported on 25 May 1919 that two American airplanes carrying lewisite could have wiped out "every vestige of life–animal and vegetable–in Berlin. A single day's output would snuff out the millions of lives on Manhattan Island."

44. Vilensky, *Dew of Death,* 44.

45. As Colonel Walker explained: Barry, "Vast U.S. Poison Gas Plant Was Working at Full Blast for 1919 Campaign," *NYT,* 8 December 1918, 45.

46. Supreme War Council: Brown, *Chemical Warfare,* 47 n.102.

47. For another account about the plans against Germany, see Edwin E. Slosson, "What Germany Escaped," *The Independent,* 7 June 1919, 355–57, 381–83.

48. WWI casualties: Ellis & Cox, *World War I Databook.*

49. Influenza deaths: Johnson & Mueller, "Updating the Accounts: Global Mortality of the 1918–1920 'Spanish Influenza' Pandemic."

50. Inevitable leakage: "Our Super-Poison Gas: First Story of Compound 72 Times Deadlier than 'Mustard,' Manufactured Secretly by the Thousands of Tons," *NYT,* 20 April 1919, SM1; Vilensky, *Dew of Death,* 52; Hershberg, *James B. Conant: Harvard to*

Hiroshima and the Making of the Nuclear Age, 47; Stockbridge, "War Inventions that Came Too Late."

51. Fries & West, *Chemical Warfare*, 187–88.

52. Vilensky, *Dew of Death*.

53. Edgewood cleanup and soil samples in 2004: Vilensky & Sinish, "Dew of Death," 54–59.

CHAPTER 6: HYDROGEN CYANIDE: THE GAS CHAMBER IS BORN

1. Part V. Section I, chapter I, Article 171, Versailles Treaty.

2. Fries mounts massive campaign against Geneva Protocol: Interview with Fries, cited in Brophy, "The Origins of the Chemical Corps," 225.

3. Fries claims "most powerful and the most humane . . . " Fries to J. D. Law, 16 August 1919, General Fries's file, Records of the Chemical Warfare Service, RG 175, National Archives.

4. Gas as cure-all: "Army Chemists Use Poison Gases on Disease; Grip, Pneumonia, Paresis Said to Be Cured," *NYT*, 2 May 1923: 1.

5. "Resultant damage to vegetation . . . " Howard, "The Needs of the World as to Entomology," 370.

6. Fries denies ill health effects from gas: "Says War Gas Leaves No Bad After Effect," *NYT*, 12 November 1923: 15.

7. President Coolidge gets gassed: "Chlorine Gas, War Annihilator, Aids President's Cold," *WP*, 21 May 1924: 1; *NYT*, 22 May 1924.

8. Fries calls gas a boon to the human race: "Scientific Warfare Aids Man, Teachers Are Told," *WP*, 30 November 1924: 7. See also Fries disputes health officials: "Gen. Fries Defends Chlorine Treatment," *NYT*, 6 January 1925: 14.

9. "Worst of all pests to handle": Amos Fries, "Address before Chemical Industries Exposition, New York City," 12 September 1922, 029.0611 Articles and Speeches – Peacetime Activities, Station Series Security Classified, RG 175.

10. Pest control and warfare: Russell, "Speaking of Annihilation," 1508–09.

11. Effects of cyanide: National Safety Council, from http://www.nsc.org/ehc/chemical/Hydrocya.htm

12. Growth of HCN in fumigation: U.S. Department of Agriculture, *Chronological History of the Development of Insecticides and Control Equipment from 1854 through 1954*.

13. "Cyanides comprise a wide range of compounds of varying degrees of chemical complexity and toxicity. Hydrogen cyanide is a colorless or pale blue liquid or gas with a faint bitter almond-like odor that was used primarily in the fumigation of ships, railroad cars, large buildings, grain silos, and flour mills, as well as in the fumigation of peas and seeds in vacuum chambers. Other cyanides, such as sodium and potassium cyanide, are solid or crystalline hygroscopic salts widely used in ore extracting processes for the recovery of gold and silver, electroplating, case-hardening of steel, base metal flotation, metal degreasing, dyeing, printing, and photography." United Nations Environment Programme, *Hydrogen Cyanide and Cyanides: Human Health Aspects*.

14. Germans dominated the U.S. market before the war: Lougheed, "The Anatomy of an International Cartel: Cyanide, 1807–1927," 3.

15. Roessler & Hasslacher: Roush, *The Mineral Industry*, 314; Lougheed, "The Anatomy of an International Cyanide Cartel," 4, 9.

16. R&H and DEGUSSA: "Head of German Society Is Held for Activities," *SH*, 12 July 1918, 1,10. DEGUSSA remains best known for its manufacture of Zyklon-B, the poison gas used to exterminate Jewish prisoners in Nazi concentration camps. In 1922 DEGUSSA took over DEGESCH (an abbreviation for the German Corporation for the Control of Vermin), which was the successor to the War Ministry's Technical Committee for Pest Control headed by Haber, which had concentrated on methods of killing lice in trenches, barracks, and submarines," and in 1920 had been converted into a corporation owned by a consortium of chemical firms. Hayes, *From Cooperation to Complicity*, chapter 1, quoted 6.

17. DEGUSSA was stripped of Roessler & Hasslacher: Hayes, *From Cooperation to Complicity*, 6.

18. Shares sold under Alien Enemy Act: "Alien Enemies' Property Sold," *LAT*, 19 July 1919.

19. Department of Agriculture response: Department of Agriculture Bulletin 1149, cited in "Hydrocyanic Acid as Fumigant for Pests," *BG* (PA), 28 December 1923, 3.

20. "Delousing" of Mexicans: For a startling account of the use of Zyklon cyanide on Mexican immigrants, see Romo, *Ringside Seat to a Revolution*.

21. Proof about Dr. Peters following American developments with Zyklon: See, e. g., Dr. Gerhard Peters, "Blausäure zur Schädlingsbekämpfung [Hydrocyanic Acid for Pest Control]," *Sammlung chemischer and chemisch-technischer Vortrage* (Stuttgart: Ferdinand Enke Verlag, 1933), Neue Folge-Heft 20, 64.

22. DEGESCH as successor to Haber's unit: Hayes, *From Cooperation to Complicity*, 4–5.

23. Richardson's wood-and-glass chamber: Richardson, "On the Painless Extinction of Life in the Lower Animals," see also Black's history of the eugenics movement, *War Against the Weak*, chapter 13.

24. D. H. Lawrence quote: Lawrence, *Fantasia of the Unconscious*, 144.

25. Victorian discourse about the lethal chamber: outlined in Black, *War Against the Weak*, 247–50.

26. Hamilton's gas chamber idea: Hamilton, *Recollections of an Alienist*.

27. Gerry Commission opts for electric chair and "death chamber." Moran, *The Executioner's Current*, 110.

28. McKim's call for the "surest, the simplest, the kindest" way to kill human beings: McKim, *Heredity and Human Progress*, 120, 168.

29. Dr. Hamilton's "most humane alternative." Hamilton, *Recollections of an Alienist*, 382–89.

30. Frank Curran's background; he advocated using gas when prisoner was asleep . . . *NSJ*, 8 February 1924, 2. Curran was born in Woburn, Massachusetts, on June 26, 1886. He was educated in Massachusetts, then at Ecole Alsacienne in France and at Boston University School of Law. He was admitted to the bar in Arizona but suffered ill health and moved to Nevada and California before returning to Battle Mountain, Nevada where he served as district attorney of Lander County. After practicing law in Nevada in 1920 he served as secretary to Senator Key Pittman (D-Nevada) during the Cox-Harding campaign. In 1922 he moved to practice law in Fresno, California and later

served as deputy district attorney of Los Angeles. See Winchell, *History of Fresno County; the San Joaquin Valley*, 246. During the World War he had joined the Army but failed to qualify for the aviation branch. Governor Scrugham Papers, Nevada State Archives.

31. Legislation to Boyle: *Las Vegas Age*, March 19, 1921; *PR*, 25 March 1921; *NSJ*, 29 March 1921; *CCDA*, 6 January 1923; *REG*, 18 January 1924; Chan, 95, 104.

32. Boyle signs Humane Execution Law: From a two-page, unpublished typescript in the Nevada State Prison Papers, File 2320, Nevada State Archives.

33. "When the condemned man is asleep . . ." "Nevada to Use Gas to Execute Criminals," *NYT*, 18 March 1921, p. 9; "Signs Nevada Law for Lethal Execution," *NYT*, 29 March 1921, p. 9. Boyle corresponded with Adolph Lewisohn, the famous philanthropist and mining tycoon who was president of the NCPPL based at Columbia University.

34. "Hidden conduits a suffocating gas." "Painless and Yet Horrible," *NYT*, 30 January 1922, 10.

35. Hughie Sing and Gee Jon charged: *State of Nevada v. Gee Jon and Hughie Sing*, Justice Court of Mina Township, Mineral County, Nev., 9 September 1921, 5, 19–20, 22, 28, 30, 39, located in criminal case file no. 56, District Court Clerk, Mineral County, Hawthorne, Nevada. Barbara Parker Weber, "Lethal Gas Execution: Nevada's Daring Experiment," *TDT*, 7 February 1999.

36. State court affirmed the conviction and held lethal gas was not unconstitutional cruel and unusual punishment: *The State of Nevada v. Gee Jon and Hughie Sing*, 46 Nev. 418, 211 P. 276, 30 A. L. R. 1443 (1923).

37. Nevada's first death house: Biennial Report of the Warden of the Nevada State Prison, 1923–1924, 3, in Gov. Scrugham Papers, Nevada State Archives; *CDM*, 8 February 1924, 4.

38. Dinsmore's gas plans: *ECT*, 22 January 1924, p. 1. Hydrocyanic acid was already being used extensively as a fumigant to destroy insects and rodents, and this usage had very recently been studied by the US Department of Agriculture to determine the quantity of the fumigant that was absorbed and retained in various foodstuffs. Results of the investigation were given in Department Bulletin 1149, which had just been issued. The report did not offer any conclusions as to the safety of fumigated foods. See "Hydrocyanic Acid as a Fumigant for Pests," *The Gazette* (Bedford, PA), 28 December 1923, 3.

39. "As this is in line with the work of the Chemical Warfare Service . . ." Letter from Major Charles R. Alley to Attorney General, State of Nevada, January 30, 1924, Nevada State Prison Files, file 2320, Nevada State Archives.

40. Problems with liquid HCN: *NSJ*, 9 March 1924, 1. The Nevadans may have been unaware that two years earlier, Water Heerdt in Germany had perfected a process for packing the volatile hydrogen cyanide in its principal product, a fumigant called Zyklon, in tins filled with small absorbent pellets. Zyklon stabilized the chemical until the cans were opened and the pellets were dumped, at which point the contents vaporized. The poison served to block the transfer of oxygen to any warm-blooded organism in the vicinity. Zyklon-B amounted to a major technological breakthrough and rapidly enjoyed commercial success. It would have been safer to transport and easier to use in the execution, since it did not require additional dipping into an acid solution. But at that time either Zyklon-B was not available on the West Coast, or the Nevadans opted against it.

41. Autofumer: *REG*, 26 January 1924, p. 1; *NSJ*, 9 March 1924, 1.

42. *REG*, 26 January 1924, 1.

43. Dickerson sent trusted staff member: *CCDA*, 15, 28 January 1924; *SFCP*, 22 January 1924; *REG*, 26 January 1924, 5 February 1924; Chan, "Example for the Nation: Nevada's Execution of Gee Jon," 99, 105. In 1923–24 American Cyanamid conducted a series of experiments, attempting to use liquefied HCN to fumigate grain elevators, but they could not get the poison to distribute evenly throughout the grain bin. American Cyanamid Co., *Research in the Development of Cynogas Calcium Cyanide*, 3–41.

44. Four guards resigned: "Ready with Death Gas," *LAT*, 7 February 1924, 1. The men who quit were identified as Harry James, John Gulling, Ed Kofed, and Richard Savage. *NSJ*, 7 February 1924, 1.

45. *NSJ*, 9 February 1924, 1.

46. Gassing commenced at 9:40 am: Delos A. Turner the Chief of Chemical Warfare Service, U.S. War Department, February 1924, NSP-2320; *YC*, 9 February 1924; *NSJ*, 9 February 1924; *SJMH*, 9 February 1924; *NYT*, 9 February 1924; Chan, "Example for a Nation," 100, 105.

47. HCN at 75 degrees . . . liquid pool: Nevada State Prison, Warden, *Biennial Report, 1923–1924*, p. 4; Chan, "Example for a Nation," 100, 105.

48. *NSJ*, 9 February 1924, 1.

49. Physicians examine corpse: *NSJ*, 9 February 1924, 2.

50. "Prefer to die that way . . . ""Witnesses Agree Lethal Gas Is Painless," *OSE*, 10 February 1924, 11.

51. " . . . upheld by . . . humanity." "Law Held Success; State Claims Life for Life by Novel Method Used for First Time in History at Carson City; End Comes Quietly, Without Pain to Tong Killer," *NSJ*, 9 February 1924, 1.

52. "Outward symbols of civilization." *SJMH*, 9 February 1924.

53. "Possibility of terrifying accidents." *NYT*, 9 February 1924, 12.

54. *New Haven Journal-Courier*: "Execution by Gas," *Literary Digest*, 1 March 1924, 17.

55. *Biennial Report of the Warden of the Nevada State Prison, 1923–1924*, 4.

56. In 13 tests, the Zyklon-B . . . Ridlon, "Experiments with Certain Fumigants used for the Destruction of Cockroaches."

57. "Pouring the contents down the hold . . . " Williams, "The Air Jet." This was one of many such reports the department issued in 1931.

58. In early 30s giant chemical firms: http://heritage.dupont.com/floater/fl_randh/floater.shtml; Lougheed, "The Anatomy of an International Cartel," 6–7.

59. Colorado hired Eaton: "2,500 for Death House," *RMN*, 15 June 1933, 14; Maurice Leckenby, "State Pen Death Chamber Nearing Completion Here," *RMN*, 24 September 1933, 6.

60. Eaton as steel fabricator . . . with Calco: "Execution Chamber Styles," *RMN*, 27 February 1938; Cary Stiff, "Denverite 'Refined' Death," *DPt*, 15 September 1966, 88; Bill Pardue, "Denver Firm Receives Inquiries on Gas Chambers," *RMN*, 6 December 1976, 43; Cary Stiff, "The Death House by the Side of the Road," *DPt*, 16 May 1971, "Empire Magazine," 17–22.

61. " . . . it gets results." United Press, *Mansfield* (OH) *News Journal*, 14 April 1938, 12.

62. Eaton's patent in 1939: Joan Smith, "The Return of the Big Green Death Machine," *San Francisco Examiner Image Magazine*, 8 January 1989, 12.

Chapter 7: The Attack That Never Came

1. Haldane's civil defense pitch: Haldane, *A. R.P.* Also see Clark, *JBS: The Life and Work of J. B. S. Haldane*; Goodman, *Suffer and Survive: The Extreme Life of J. S. Haldane.*

2. War of the Worlds: "An Invasion from the Planet Mars," *PI*, 1 November 1938, 1; "Radio Listeners in Panic, Taking War Drama as Fact: Many Flee Homes to Escape 'Gas Raid From Mars'— Phone Calls Swamp Police at Broadcast of Wells Fantasy," *NYT*, 31 October 1938.

3. Houseman, "The Men from Mars."

4. Changing American public opinion . . . See Johnston, *Bridge Not Attacked: Chemical Warfare Civilian Research during World War II.*

5. Himmler's plan . . . Hitler's reluctance: See, e. g., Breitman, *The Architect of Genocide*, 166, 289 n.95 citing the Gerhard Peters affidavit, United States National Archives, War Crimes, Record Group 238, Microfilm Series T-301/R 99/700, NI-12111. Moon, "Chemical Weapons and Deterrence."

6. Bernstein, "Why We didn't Use Poison Gas in World War II."

7. FDR says, "If Japan persists . . . " FDR Papers, 1942, 258.

8. FDR clarifies policy: FDR papers, 1943, 243.

9. Bernstein, "Why We Didn't Use Poison Gas in World War II."

10. Ambros to Hitler: Moon, "Chemical Weapons and Deterrence," 26; Bower, *The Paperclip Conspiracy*, 93–94.

11. Bernstein.

12. Bernstein; Moon, "Chemical Weapons and Deterrence."

13. Churchill's quotes on gas have been widely reprinted. See, e. g., Guenther W. Gellermann, *"Der Krieg, der nicht stattfand"* (Bernard & Graefe Verlag, 1986), 249–51; Martin Gilbert, *Churchill: A Life* (New York: Macmillan, 1992), 782.

14. Gilbert, *Churchill: A Life*, 782–84.

15. Hebrew Committee to Joint Chiefs: National Archives, Washington, D.C., Record Group 218, the Records of the Joint Chiefs of Staff, JCS, especially file CCS 385.3. See also Mendelsohn, 129–52.

16. National Archives, Washington, D.C., Record Group 218, Records of the Joint Chiefs of Staff, JCS 1072: Retaliation for the Extermination of Hebrews in Europe by the Use of Poisonous Gases, 26 September 1944, CCS 385.3.

17. Attack from Bavaria: British War Office 219/1986 4/9/45.

18. Hitler held back after Bari: Infield, *Disaster from Bari*; and Reminick, *Nightmare in Bari.*

19. Army tests gases in caves before invading Japan: Moon, "Chemical Weapons and Deterrence," 22–23.

20. Thomas B. Allen and Norman Polmar, "Poisonous Invasion Prelude," *PPG*, 4 August 1995.

21. U.S. policy on weapons of mass destruction at the end of the war: Moon, "Pressing the Limits."

22. Allen and Polmar, "Poisonous Invasion Prelude."

Chapter 8: Holocaust: Carbon Monoxide, Zyklon-B Hydrogen Cyanide

1. Hitler's gassing; " . . . burning coals . . . " O'Donnell, *The Bunker*, p. 110; Groom, *A Storm in Flanders*, 245.

2. Dawidowicz, *The War Against the Jews*, 92.

3. Karl Brandt was later convicted at the Doctor's Trial in Nuremberg and hanged as a war criminal.

4. Hitler's authorization to Brandt and Bouhler on "mercy death": Friedlander, T*he Origins of Nazi Genocide*: 131–34. An excellent history of the Nazis' program of medicalized killing and euthanasia is found in Lifton, *The Nazi Doctors: Medical Killing and the Psychology of Genocide.*

5. Lifton, *The Nazi Doctors.*

6. Viktor Brack, quoted in U.S. Military Tribunal, "Case 1, The Medical Case, testimony of Viktor Brack, in *Trials of War Criminals* (Washington, D.C.: U.S. Government Printing Office, 1949); Friedlander, *The Origins of Nazi Genocide*, 88.

7. Friedlander, *The Origins of Nazi Genocide*, 96.

8. Lifton, *The Nazi Doctors*, 96.

9. Becker and Eberl: Lifton, *The Nazi Doctors*; Friedlander, *The Origins of Nazi Genocide*, 88–90.

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About the Author

Scott Christianson is the author of numerous books of investigative history including *With Liberty for Some* (winner of a Robert F. Kennedy Book Award), *Freeing Charles*, and *The Last Gasp*. Hundreds of his articles have appeared in *The New York Times*, *Journal of American History*, *The Nation*, and other journals. He also works in documentary films, exhibits, and new media as well as appearing frequently on television and radio. Dr. Christianson has taught at Bard College, Rensselaer Polytechnic Institute, and the State University of New York at Albany. He lives in upstate New York with his wife and son.

(continued from front flap)

mustard gas, lewisite, hydrogen cyanide, and the nerve agents tabun, sarin, soman, VX, and methyl isocyanate. The book also examines some naturally occurring gases, such as carbon dioxide, sulfur dioxide, hydrogen sulfide, carbon monoxide, methane, and radon. Colorful accounts capture the characteristics and history of each of these mysterious substances, focusing on key episodes in scientific discovery and exploration since World War I.

SCOTT CHRISTIANSON, PhD, is an award-winning author, investigative reporter, and filmmaker whose books include *With Liberty for Some: 500 Years of Imprisonment in America* and *The Last Gasp: The Rise and Fall of the American Gas Chamber.* He lives in upstate New York.

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IN PRAISE OF FATAL AIRS

"*Fatal Airs* is a wake-up call for all who thought chemical warfare was a thing of the past. Christianson meticulously traces the evolution of poison gases once used in warfare to their industrial use today. A small group of these industrial chemicals, such as chlorine gas, put millions of Americans at risk even though safer alternatives are readily available. *Fatal Airs* is a compelling reminder that we have yet to apply the most important lessons of 9/11."

Rick Hind
Legislative Director, Greenpeace

"Scott Christianson has kept alive stories of lethal gas—in the trenches of World War I, in the execution chambers of U.S. prisons, in Nazi concentration camps, in Bhopal, India, in Kurdistan—that recall and commemorate the many lives these gases extinguished. Christianson also tells stories about the discovery and development of laughing gas (nitrous oxide), chlorine, phosgene, and cyanide—gases that both kill, and undergird industrial society. Interwoven are stories about IG Farben, DuPont, Union Carbide, and Dow, the corporate leaders of industrial society. In connecting these stories, Christianson compels one to think about how necessary, and difficult, building different kinds of societies will be."

Professor Kim Fortun
Rensselaer Polytechnic Institute, Author of *Advocacy after Bhopal: Environmentalism, Disaster, New Global Orders*, and coeditor of *Cultural Anthropology*

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