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A Glance Back – Myths and Facts about CBRN Incidents

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In our human history we can find numerous examples of the application of chemical and biological agents used or proposed as weapons during the course of a campaign or battle. In the twentieth century we saw the rise of a new age in battle field tactics and the abuse of detailed scientific knowledge for the employment of chemicals as warfare agents (CWAs). Another step that crossed a border was the use of nuclear bombs against Nagasaki and Hiroshima in 1945. Although there have been many attempts to ban chemical, biological, radiological, and nuclear warfare agents (CBRN agents), their devastating potential makes them still attractive for regular armies as well as for terrorists. Therefore, it is likely that the emergence of CBRN terrorism is going to be a significant threat in the twenty-first century. However, we need to understand our history if we want to find appropriate answers for current and future threats. For this reason, in this chapter we provide a short history of CBRN, from the beginning of the use of CBRN agents up to the emergence of CBRN terrorism and the attempt to ban the use of this threat by negotiation and treaties.

1.1
Introduction

Why do we fear the use of chemical, biological, and nuclear weapons? What are the reasons behind the obvious? To answer these questions we have to understand that data and facts are only one part of the story. To understand and to be able to lift the veil of myths about CBRN incidents we need a lot more. Therefore, the history section of this part attempts to lay the basis for a deeper understanding of subsequent chapters.

CBRN Protection: Managing the Threat of Chemical, Biological, Radioactive and Nuclear Weapons,
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1.2
History of Chemical Warfare

We can find many examples (Figure 1.1) of how the toxic principle of chemical substances has been used to ambush the enemy, even if the exact mechanism was unknown.

- **Chemical warfare weapon (CWA)**: "… The term *chemical weapon* is applied to any toxic chemical or its precursor that can cause death, injury, temporary incapacitation, or sensory irritation through its chemical action …" (*http://www.opcw.org/about-chemical-weapons/what-is-a-chemical-weapon/*, accessed 26 January 2011)
- **Chemical warfare (CW) agent**: "… The toxic component of a chemical weapon is called its "*chemical agent*." Based on their mode of action (i.e., the route of penetration and their effect on the human body), chemical agents are commonly divided into several categories: choking, blister, blood, nerve, and riot control agents." (*http://www.opcw.org/about-chemical-weapons/types-of-chemical-agent/*, accessed 26 January 2011).

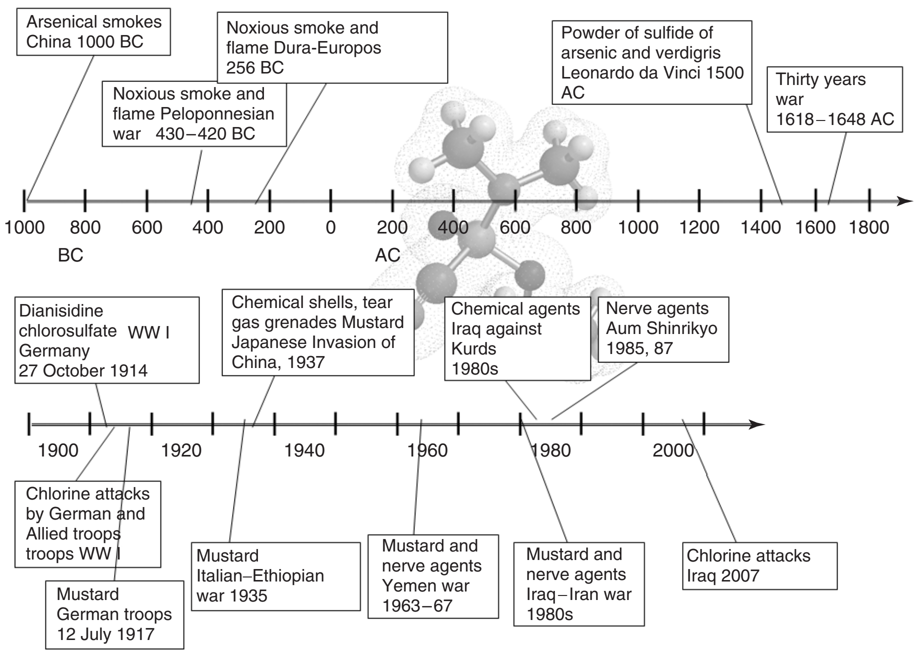

Figure 1.1 Time line of some significant examples of the application of toxic substances as chemical agents.

The deployment of toxic smokes and poisoned fire for advantage in skirmishes and on the battlefield was well known by our ancestors [1, 2]. In addition, we can date some significant changes, where the next level was reached in the discovery and use of toxic chemicals (see Figure 1.4 below).

1.2.1 Chemical Warfare Agents in Ancient Times

We can date the employment of chemicals as chemical warfare agents (CWAs) from at least 1000 BC when the Chinese used arsenical smokes [1]. By the application of noxious smoke and flame the allies of Sparta took an Athenian-held fort in the Peloponnesian War between 420 and 430 BC. Stink bombs of poisonous smoke and shrapnel were designed by the Chinese, along with a chemical mortar that fired cast-iron stink shells. Other conflicts during succeeding centuries saw the use of smoke and flame. However, it is difficult to confirm historical reports about incidents with chemicals by historical facts. One example of the confirmed use of toxic smoke is the siege of the city Dura-Europos by the army from the Sasanian Persian Empire around AD 256, where poisoned smoke was introduced to break the line of Roman defenders [3]. The full range of ancient siege techniques to break into the city, including mining operations to breach the walls, has been discovered by historians [3]. Roman defenders responded with ‘‘counter-mines’’ to thwart the attackers. In one of these narrow, low galleries a pile of bodies, representing about 20 Roman soldiers still with their arms, was found (Figure 1.2). Findings from the Roman tunnel revealed that the Persians used bitumen and sulfur crystals to start it burning. This confirmed application of poison gas in an ancient siege is an example of the inventiveness of our ancestors.

Toxic smoke projectiles were designed and used during the Thirty Years War (1618–1648). Leonardo da Vinci proposed a powder of arsenic sulfide and verdigris in the fifteenth century. Venice employed unspecified poisons in hollow explosive mortar shells during the fifteenth and sixteenth centuries. The Venetians also sent contaminated chests to their enemy to envenom wells, crops, and animals. During the Crimean War (1853–1856), the use of cyanide-filled shells was proposed to break the siege of Sevastopol. However, all these incidents happened without knowing the exact mechanism of poisoning.

1.2.2 Birth of Modern Chemical Warfare Agents and Their Use in World War I

We can date the birth of modern chemical warfare agents (CWAs) to the early twentieth century. Progress in modern inorganic chemistry during the late eighteenth and early nineteenth centuries and the flowering of organic chemistry worldwide during the late-nineteenth and early-twentieth centuries generated renewed interest in chemicals as military weapons. The chemical agents first used in combat during World War I were eighteenth- and nineteenth-century discoveries (Table 1.1).

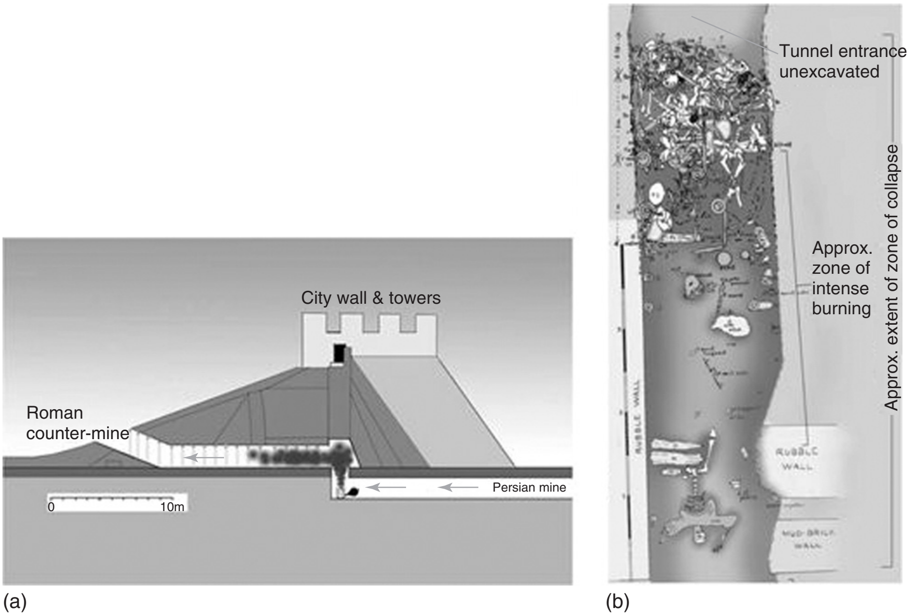

Figure 1.2 Siege of Dura-Europos by an army from the Sasanian Persian Empire (around AD 256 [3]): (a) The Sasanian Persian mine designed to collapse Dura's city wall and adjacent tower. The Roman countermine intended to stop them and the probable location of the inferred Persian smoke-generator thought to have filled the Roman gallery with deadly fumes. (b) A composite plan of the Roman countermine, showing the stock of Roman bodies near its entrance. The area of intense burning marks the gallery's destruction by the Persians and the skeleton of one of the attackers. Credit: images copyright of Simon James.

Table 1.1 Important eighteenth- and nineteenth-century discoveries of toxic chemicals.

Year	Name	Discovery
1774	Carl Scheele, a Swedish chemist	Discovery of chlorine in 1774. He also determined the properties and composition of hydrogen cyanide in 1782
1802	Comte Claude Louis Berthollet, a French chemist	Synthesis of cyanogen chloride
1812	Sir Humphry Davy, a British chemist	Synthesis of phosgene
1822	Victor Meyer, a German chemist	Dichloroethyl sulfide (mustard agent) was synthesized in 1822, again in 1854, and finally fully identified in 1886
1848	John Stenhouse, a Scottish chemist	Synthesis of chloropicrin

In 1887, the use of tear agents (lacrimators) for military purposes was considered in Germany. In addition, a rudimentary chemical warfare program was started by the French with the development of a tear gas grenade containing ethyl bromoacetate. Furthermore, there were some discussions in France about the filling of artillery shells with chloropicrin. The French Gendarmerie had successfully employed riot-control agents for civilian crowd control. These agents were also used in small quantities in minor skirmishes against the Germans, but were largely inefficient. In summary, these riot-control agents were the first chemicals applied on a modern battlefield, and the research for more effective agents continued throughout the war.

In the early stages of World War I, the British examined their own chemical technology for battlefield use. Their first investigations also covered tear agents, but later they put their effort towards more toxic chemicals. Nevertheless, the first large-scale employment of chemicals during World War I was initiated by heavily industrialized Germany. Three thousand 105-mm shells filled with dianisidine chlorosulfate, a lung irritant, were fired by the Germans at British troops near Neuve-Chapelle on the 27 October 1914, but with no visible effect [4]. Nonetheless, the British were the victims of the first large-scale chemical projectile attack. The Germans continued firing modified chemical shells with equally unsuccessful results. This lack of success, and the shortage of artillery shells, led to the concept of creating a toxic gas cloud directly from its storage cylinder. This concept was invented by Fritz Haber in Berlin in 1914.

The first great attack with CWAs in modern warfare: Ypres in Belgium. Chlorine attack by German troops in April 1915 [5].

German units placed a total of between 2000 and 6000 cylinders opposite the Allied troops defending the city of Ypres in Belgium. The cylinders contained a total of around 160 tons of chlorine. Once the cylinders were in place, and because of the critical importance of the wind, the Germans waited for the winds to shift to a westerly direction toward the trenches of the Allied troops. During the afternoon of the 22 April 1915 the chlorine gas was released with devastating effects. This attack caused between 800 (realistic) and 5000 (mainly propaganda) deaths.

After the first great attack with chemical warfare agents (CWAs) by German troops near Ypres [5], the Allied troops quickly restored a new front line and it took only a short period of time for them to be able to use chlorine themselves. In September 1915, they launched their own chlorine attack against the Germans at Loos. The expansion of the armamentarium with chloropicrin and phosgene was just the beginning of a deadly competition between both sides [6]. We saw the invention and the development of more protective masks, more dangerous chemicals, and improved delivery systems.

Table 1.2 Estimated chemical casualties in World War I.

Country	Nonfatal chemical casualties	Chemical fatalities
Russia	420 000	56 000
Germany	191 000	9000
France	182 000	8000
British Empire	180 000	8100
United States	71 000	1500

A further step in a devastating chemical war was the use of a new kind of chemical agent. On the 12 July 1917, again near Ypres in Belgium, sulfur mustard was spread by the Germans in an artillery attack. Compared to the first agents, mustard was a more persistent vesicant on the ground, and this caused new problems. Not only was the air poisoned, but the ground and equipment was also contaminated. This new agent was effective in low doses and affected the lungs, the eyes, and also the skin. Although fewer than 5% of mustard exposed soldiers died, mustard injuries could easily overwhelm the medical system. Therefore, the need for protective equipment for soldiers and horses that were heavy and bulky at that time led to more difficult and dangerous fighting. In summary, World War I was the dawn of a new military age with devastating effects, with Russia bearing the heaviest burden of chemical casualties (Table 1.2).

1.2.3
Chemical Warfare Agents between the Two World Wars

Throughout the 1920s there was evidence that the military use of chemical agents continued after the end of World War I. Germany worked with Russia, which had suffered nearly half a million chemical casualties during World War I, to improve their chemical agent offensive and defensive programs from the late 1920s to the mid-1930s. During the Russian Civil War and Allied intervention in the early 1920s both sides had chemical weapons, and there were reports of isolated chemical attacks. Later accounts accused the British, French, and Spanish troops of using chemical warfare at various times and places during the 1920s. For example, it is rumored that Great Britain employed chemicals against the Russians and mustard against the Afghans north of the Khyber Pass. Spain has been accused of having deployed mustard shells and bombs against the Riff tribes of Morocco [7].

1.2.3.1 The Italian–Ethiopian War

During the Italian–Ethiopian War the first major employment of chemical weapons after World War I was reported. On 3 October 1935, Mussolini launched an invasion of Ethiopia from its neighbors Eritrea and Italian Somaliland. Italian troops dropped mustard bombs and sprayed it from airplane tanks. Mustard agent was selected as a "dusty agent" to burn the unprotected feet of the Ethiopians with devastating effects. It was the first time special sprayers were prepared on board of aircrafts to vaporize a fine, deathly rain. This fearful tactic succeeded and by May 1936 the Ethiopian army was completely routed and Italy controlled most of Ethiopia, until 1941 when British and other allied troops re-conquered the country. However, some have concluded that the Italians were a clearly superior force and that the use of chemical agents in the war was nothing more than an experiment. Nonetheless, there were thousands of victims of Italian mustard gas [7].

1.2.3.2 Japanese Invasion of China

The Japanese had an extensive chemical weapons program. They were producing agent and munitions in large numbers by the late 1930s. During the invasion of China in 1937 it was reported that Japanese forces began using chemical shells, tear gas grenades, and lachrymatory candles. In 1939, there was an escalation by the Japanese that led to the application of mustard and lewisite with great effect. The Chinese troops retreated whenever they saw smoke, thinking it was a chemical attack [8].

1.2.3.3 First Nerve Agents

Searching for more potent insecticides the German chemist Schrader of the IG Farben Company discovered an extremely toxic organophosphorus insecticide in 1936. This new compound was reported to the Chemical Weapons Section of the German military prior to patenting, as required by German law of that time. The substance had devastating effects on the nervous system and was therefore classified for further research. The substance was named tabun and after World War II it was designated GA, for "German" agent "A." The research continued and in 1938 a similar agent, sarin (GB), was designated with toxicity five-times higher than that of tabun.

1.2.4 Chemical Warfare Agents in World War II

It is due to common sense that chemical warfare agents (CWAs) were not widely used in World War II. However, pilot plants for production were built on both sides. Germany produced and weaponized approximately 78 000 of tons of CWAs. The key agent was mustard in terms of production. The Germans filled artillery shells, bombs, rockets, and spray tanks with the agent. Why these deadly agents were not used on the battlefield remains a mystery. Thus, the top-secret German nerve agent program remained a secret until its discovery by the Allies after the end of World War II.

Furthermore, there are reports, that Japan produced about 8000 tons of chemical agents during the war. The favored agents were mustard agent, a mustard–Lewisite mixture, phosgene, and hydrogen cyanide. They gained experience during their attacks on China.

The greatest producer of chemical warfare agents (CWAs) during World War II was the United States of America. Ready for retaliation, if Germany had been used chemical warfare agents (CWAs), the United States produced proximately 146 000 tons of chemical agents between 1940 and 1945. With the possible exception of Japan during attacks in China no nation though, employed chemical agents on the battlefield during World War II. However, the positioning of chemical weapons near the front line in case of need resulted in one major disaster in 1943 [9]. In 1943 the Germans bombed the American ship the *John Harvey* in Bari Harbor, Italy. This was a ship loaded with 2000 100-pounds M47A1 mustard bombs. Over 600 military casualties and an unknown number of civilian victims resulted from the raid when they were poisoned by ingestion, skin exposure to mustard-contaminated water, and inhalation of mustard-laden smoke. The harbor clean-up took more than three weeks.

1.2.5
Chemical Warfare Agents during the Cold War

The end of World War II did not stop the development, stockpiling, or use of chemical weapons. During the Yemen War of 1963 through 1967, Egypt in all probability used mustard and nerve agents in support of South Yemen against royalist troops in North Yemen. Attacks occurred on the town of Gahar and on the villages of Gabas, Hofal, Gadr, and Gadafa. Shortly after these attacks, the International Red Cross examined victims, soil samples, and bomb fragments, and officially declared that chemical weapons, identified as mustard agent and possibly nerve agents, had been applied in Yemen [10]. Prior to this, no country had employed nerve agents in combat. The combination of the use of nerve agents by the Egyptians in early 1967 and the outbreak of the war between Egypt and Israel during the Six-Day War in June finally attracted world's attention to the events in Yemen.

The USA, which used napalm, defoliants, and riot-control agents in Vietnam and Laos, finally ratified the Geneva Protocol in 1975, but with the stated reservation that the treaty did not apply either to defoliants or riot-control agents. During the late 1970s and early 1980s, reports of the application of chemical weapons against the Cambodian refugees and against the Hmong tribesmen of central Laos surfaced, and the Soviet Union was accused of using chemical agents in Afghanistan. Widely publicized reports of Iraqi's employment of chemical agents against Iran during the 1980s led to a United Nations investigation that confirmed the attack by the vesicant mustard and the nerve agent tabun. Later during the war, Iraq apparently also began to apply the more volatile nerve agent sarin, and Iran may have used chemical agents to a limited extent in an attempt to retaliate for Iraqi attacks. After the conflict with Iran, Iraq's Saddam Hussein employed chemical weapons to deal with rebellious Iraqi Kurds who had been assisted by the Iranians. The Iraqis used mustard, possibly combined with nerve gases, against the Kurdish town of Halabja in March 1988, killing thousands of people.

Halabja: After two days of conventional artillery attacks gas canisters were dropped on the town on 16 March 1988. The gas aggression began early in this day's evening after a series of napalm and rocket attacks, when a group of up to 20 Iraqi MiG and Mirage aircraft began dropping chemical bombs. The town and surrounding district were further assaulted with conventional bombs and artillery fire. At least 5000 people died as an immediate result of the chemical attack (Figure 1.3) and it is estimated that a further 7000 people were injured or suffered long-term illness. The attack is believed to have included the nerve agents tabun, sarin, and VX, as well as mustard gas.

Figure 1.3 Dead people in Halabja. Image is public domain.

Other countries that have stockpiled chemical agents include countries of the former Soviet Union, Libya (the Rapta chemical plant, part of which may still be operational), and France. Over two dozen other nations may also have the capability to manufacture offensive chemical weapons. The development of chemical warfare programs in these countries is difficult to verify because the substances used in the production of chemical warfare agents (CWAs) are in many cases the same substances that are applied to produce pesticides and other legitimate civilian products.

1.2.6
Chemical Warfare Agents Used in Terrorism

Although terrorism was not unknown in the world through the twentieth century, it was not really widespread until the 1980s. Then the issue began to acquire a higher profile. Aside from some domestic terrorism from the left in the United States during the late 1960s and into the 1970s, most notably in the form of the "Weather Underground" group, by the end of that decade the focus had turned toward the right, first in the form of the "Survivalists" movement and then the rightist/white supremacist "militias" that followed them. In other countries similar organizations, sometimes with a religious background, also presented a potential domestic terroristic threat. One well-known example is the Japanese religious cult,

Table 1.3 Chlorine attacks in Iraq.

Date	Event
21 October 2006	A car bomb carrying 12 120 mm mortar shells and 2 100-pound chlorine tanks detonated in Ramadi
28 January 2007	A suicide bomber drove a dump truck packed with explosives and a 1-ton chlorine tank into an emergency response unit compound in Ramadi
February 2007	Three attacks with chlorine took place in the cities of Ramadi and Baghdad
March 16 2007	Three separate suicide attacks in this month used chlorine in Ramadi and Fallujah
March 28 2007	Suicide bombers detonated a pair of truck bombs, one containing chlorine
April 2007	Three attacks with chlorine where reported in Ramadi and Baghdad
15 and 20 May 2007	Chlorine was used in Abu Sayda and nearby Ramadi
3 June 2007	A car bomb exploded outside a US military base in Diyala, unleashing a noxious cloud of chlorine gas

Aum Shinrikyo. They released nerve agents (sarin) in Matsumoto, Japan, 1994 and in 1995 they used sarin in a crowded Tokyo subway. This is an example of how the employment of chemical warfare agents (CWAs) by terrorists could be a significant threat to the civilian population.

Another actual example is the use of chlorine in Iraq. Chlorine bombings in Iraq began as early as October 2006, when insurgents in the Al Anbar Province started applying chlorine gas in conjunction with conventional vehicle-borne explosive devices (Table 1.3). The inaugural chlorine attacks in Iraq were described as poorly executed, probably because much of the chemical agent was rendered nontoxic by the heat of the accompanying explosives. Subsequent, more refined, attacks resulted in hundreds of injuries, but have proven not to be a viable means of inflicting massive loss of life. Their primary impact has therefore been to cause widespread panic, with large numbers of civilians suffering non life-threatening, but nonetheless highly traumatic, injuries.

1.2.7 Conclusions and Outlook

Parallel to technological developments we have seen the more and more sophisticated use of toxic substances in warfare over the centuries. The understanding of the mechanism of action of chemicals as chemical warfare agents (CWAs) is closely linked to the breakthrough in science and industrial manufacturing over the centuries. From a historical point of view it is important to flag and to understand the periodic leaps by which the use and knowledge of chemicals as chemical warfare agents (CWAs) reached a new phase (Figure 1.4). Therefore it is likely that

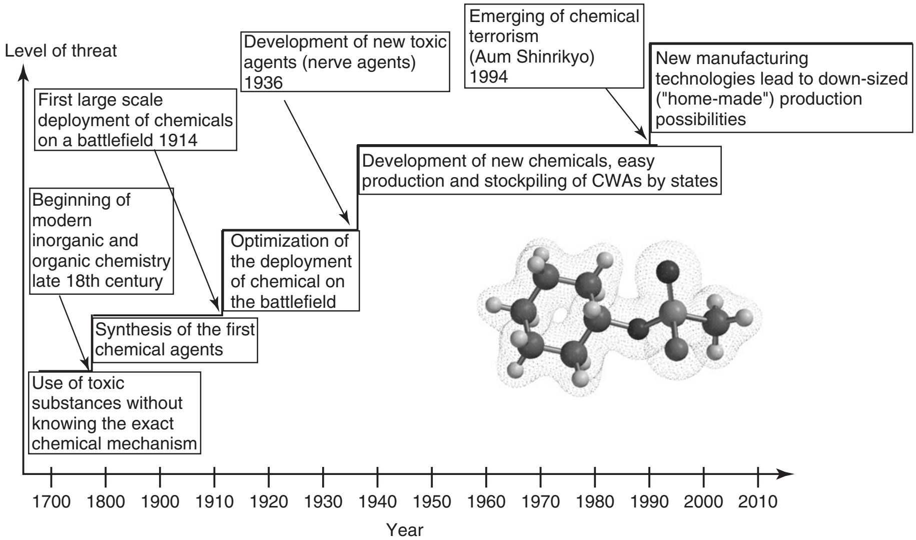

Figure 1.4 Breakthroughs in natural science and industrial development led to important leaps in the development and deployment of toxic substances in human history.

future breakthroughs in natural science and nanotechnology could lead to further leaps in the development of toxic substances designed for chemical warfare.

1.3 Introduction to Biological Warfare

The fear that the possible use of biological agents as weapons could lead to devastating effects for our civilization, economy, and society is still anchored in our minds. Therefore, if we want to estimate the potential of biological agents correctly it is necessary that we understand our history. Natural epidemics of cholera and plague are frightening enough. The notion that rogue states or terrorists could harness these and other diseases as weapons of war is even more chilling. While rare, the use of biological weapons dates back centuries. In this chapter confirmed and unconfirmed examples of biological warfare and bioterrorism are explored, from medieval times to today (Figure 1.5). We will learn more about the reasons why we still have in our memory the devastating effects of illness and a war outside the normal rules of engagement.

- **Biological warfare agents**: the use of disease-producing microorganisms, (bacteria, viruses) and toxic biological products, to cause death or injury to humans, animals, or plants.

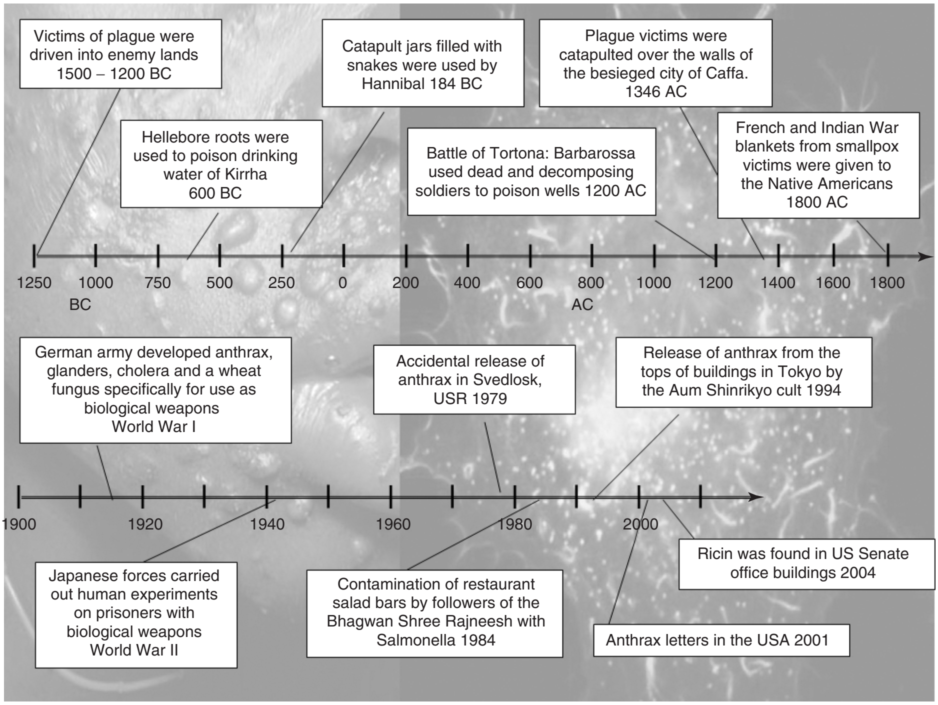

Figure 1.5 Time line of some significant examples of the application of biological substances as biological agents.

1.3.1 Most Harmful Pandemics in History

In our collective human memory the different pandemics of our history are deeply anchored. We can number several different pandemics with a high death toll (Figure 1.6). Even if the death toll is not high, fear can overcome civilizations that a disease will spread across their population.

- **Pandemic**: A pandemic is an epidemic (an outbreak of an infectious disease) that spreads across international and natural borders, or at least across a large region. A pandemic can start when three conditions have been met: (i) emergence of a new or old disease with a low protection level in a population; (ii) the disease is infectious: agents infect humans, causing serious illness; and (iii) agents spread easily and sustainably among humans.

To get a clue of the heavy death toll of pandemics and epidemics we shed light on plagues and influenzas [11]. The Peloponnesian War Pestilence wiped out over

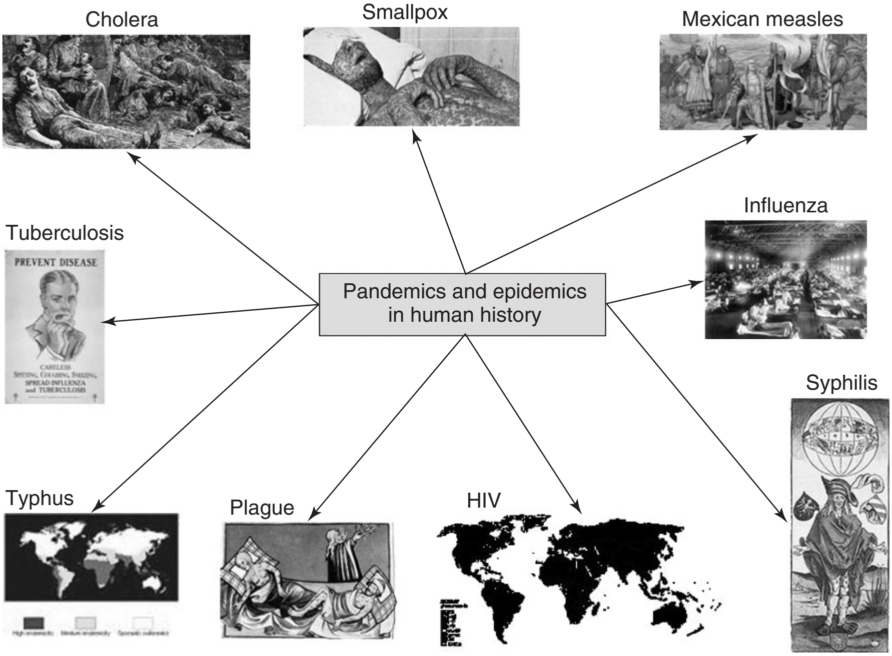

Figure 1.6 Most dangerous pandemics and epidemics in history for human kind. Images are public domain.

30 000 citizens of Athens in 430 BC (roughly one- to two-thirds of the population). Later the Antonine Plague, nowadays thought to be smallpox, was brought to Rome by soldiers returning from Mesopotamia in 165 AD. It was reported that at its peak the disease killed some 5000 people a day in Rome. Finally, 15 years later, a total of 5 million people were dead. The Plague of Justinian (541–542 AD) was recorded as a deadly disease in the Byzantine Empire. At the cumulus of the infection 10 000 people in Constantinople were killed every day. By the end of the outbreak, nearly half of the inhabitants of the city were dead. After the Plague of Justinian, there were many sporadic outbreaks of the plague, but none as severe as the ''Black Death'' of the fourteenth century. As the origin of the outbreak is unknown this pandemic took a heavy toll on Europe. The fatality level was recorded as over one-fourth of the entire European population. The last epidemic started in 1855 with the initial outbreak in Yunnan Province, China. The disease spread from China to India, Africa, and the American continent. All in all, this pandemic lasted about 100 years (it officially ended in 1959) and claimed over 12 million people in India and China alone.

In human history different influenzas have came across the world [11]. In recent history the highest death toll can be charged to ''Spanish Flu.'' ''Spanish Flu'' started in March 1918, in the last months of World War I, with an unusually virulent and deadly flu virus. Just six months later the flu had become a worldwide pandemic in all continents, with the result that half of the world's population (1 billion people) had contacted it. From what we know, it is perhaps the most lethal pandemic in the recent history of humankind. Calculations differ between 20 and 100 million dead – more than the number of people killed in the World War I itself. Since then different influenzas have plagued the world. The ''Asian Flu Pandemic'' (1957–1958) and ''Hong Kong Flu'' (1968) caused a total of nearly 2 million deaths. The ''Swine Flu Threat'' (1976), ''Russian Flu Threat'' (1977), and ''Avian Flu Threat'' (1997) illustrated that the danger of a potential major pandemic cannot be denied. The ability of influenza viruses to change, become more transmissible among people, and be more difficult to treat is an ongoing concern. Therefore, for illustration, if we have in mind that possible pandemics could wipe out one-fourth of the Asian, European, or American population nowadays, it is more than understandable why we fear the biological nightmare and want to be prepared.

1.3.2
Biological Warfare Agents in Ancient Times BC

Ever since humans brought war upon each other more soldiers have been incapacitated by diseases than by the hand of their human enemies. This observation might have led to the early deployment of poisonous substances during war. The earliest documented incident of the intention to use biological weapons is recorded in Hittite texts of 1500–1200 BC, in which victims of plague were driven into enemy lands. Although the Assyrians knew of ergot, a fungus of rye with effects similar to LSD (lysergic acid diethylamide), there is no evidence that they poisoned enemy wells with ergot, as has often been claimed. In 600 BC Solon of Athens put hellebore roots in the drinking water of Kirrha. About 200 BC, the Carthaginians used mandrake root left in wine to sedate the enemy. To our current knowledge, poisons have been administered to enemy water supplies as early as the sixth century BC. Animal cadavers substituted for poisons during the Greek and Roman eras and Emperor Barbarossa applied human corpses to the same end, although it is likely that there was no intention of spreading disease but rather a simple spoiling of water supply. A more active approach was suggested by Hannibal, who advised the Bithynians to catapult jars filled with snakes toward enemy ships in 184 BC. The panic created rather than poisonous bites likely decided the battle, revealing human psychology as a second important dimension during biological attacks. Catapulting infected human bodies and excrement constituted a further step during the sieges of many towns, although it is not clear if these actions contributed much to the spread of disease.

Can We Be Sure about Historical Reports of Biological Incidents?

There is the legend that during the siege of the Crimean city of Caffa (now: Feodosiya, Ukraine) by the Tartars in 1346 victims of the bubonic plague were catapulted into the city and an outbreak of the Black Death were reported. As the conquered Genoese fled and the victors moved on both were spreading the disease (Figure 1.7). Plague doctors were specifically hired by citizens to treat nearly everyone – the rich and the poor (Figure 1.8). At the end of the Black Death more than 25% of the European and Chinese population were dead, changing the course of human history.

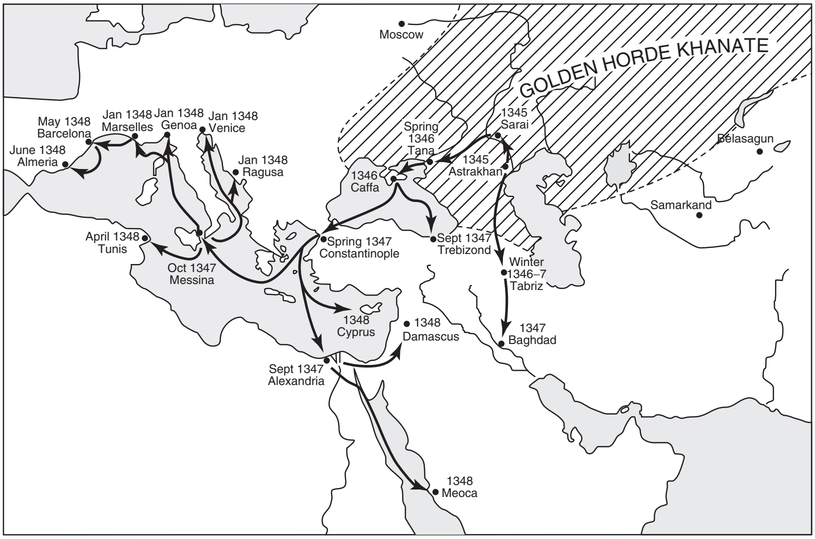

Figure 1.7 Tentative chronology of the initial spread of plague in the mid-fourteenth century. Figure taken from Reference [12].

Figure 1.8 Illustration of a plague doctor (''Doctor Beak from Rome''), engraving Rome 1656). Image is public domain.

However, whether biological warfare or less spectacular hygienic reasons were the beginning of this greatest of the medieval disasters is nearly impossible to prove. Are we able to find simple reasons for the outbreak of the disease?

- the fleas that transmit the disease between humans leave dead bodies rather quickly; this leads to the question of whether the corpses that flew into Caffa were flea infested;
- the rats moving in and out of the city walls – they also could spread the disease much more efficiently;
- it is not clear if the attackers intended to spread the disease among the besieged citizens or simply wanted to get rid of their dead comrades.

These possible reasons illustrate one of the biggest problems in biological warfare history. It is extremely difficult to distinguish between an attack that started the spread of infections and a coincidental natural infection in an ‘‘unnaturally’’ large aggregation of or new encounters between humans [13].

1.3.3 Biological Warfare Agents in the Middle Ages to World War I

During the Middle Ages, victims of the plague and decomposing bodies of humans and animals were used for biological attacks, often by throwing corpses over castle walls by catapults. It is reported that these tactics were not only applied during the siege of Caffa in 1346 [12] but also in the siege of Thun l'Évêque in 1340 during the 100 Year's War and during the siege of Karlštejn Castle in Bohemia in 1422. The last known incident of employing plague corpses for biological warfare took place in 1710. Russian forces catapulted plague-infected corpses over the city walls of Reval (today Tallinn). The Native American population was decimated after contact with the Old World due to the introduction of many different fatal diseases. There is one documented case of alleged germ warfare late in the French and Indian War. The British commander Lord Jeffrey Amherst and Swiss-British officer Colonel Henry Bouquet gave smallpox-infected blankets to Indians as part during the Siege of Fort Pitt (1873).

1.3.4 From World War I to World War II – the Beginning of Scientifically Based Biological Weapons Research

Heinrich Hermann Robert Koch (11 December 1843 to 27 May 1910) (Figure 1.9) was a German physician. He became famous for isolating *Bacillus* *anthracis* (1877), *Tuberculosis bacillus* (1882), and *Vibrio cholera* (1883). Koch's postulates founded modern microbiology. He was awarded a Nobel Prize for his tuberculosis findings in 1905. Robert Koch also inspired such major persons as Paul Ehrlich and Gerhard Domagk.

Figure 1.9 Heinrich Hermann Robert Koch. Image is public domain.

The breakthrough and foundation of modern microbiology by Robert Koch can be dated to the end of the nineteenth century. It was not only a breakthrough for our modern health care system. Unfortunately, this date marked also the beginning of the use of modern science for biological warfare. During World War I, the German Army developed anthrax, glanders, cholera, and a wheat fungus specifically for use as biological weapons. They allegedly spread plague in St. Petersburg, Russia, infected mules with glanders in Mesopotamia, and attempted to do the same with the horses of the French Cavalry. During the Sino-Japanese War (1937–1945) and World War II, Japanese forces operated a secret biological warfare research facility (Unit 731) in Manchuria, China [14]. They exposed more than 3000 prisoners to Yersinia pestis, Bacillus anthracis, Treponema pallidum, and other agents in an attempt to develop and observe the disease. In military campaigns, the Japanese army applied biological weapons on Chinese soldiers and civilians. For example, in 1940, Ningbo was bombed with ceramic bombs full of fleas carrying the bubonic plague. It is estimated that 400 000 Chinese died as a direct result of Japanese field testing of biological weapons. In 1942, the United States of America formed the War Research Service. Anthrax and botulinum toxin initially were investigated for use as weapons. Sufficient quantities of botulinum toxin and anthrax were stockpiled by June 1944 to allow unlimited retaliation if the German forces first applied biological agents. The British also tested anthrax bombs on Gruinard Island off the northwest coast of Scotland in 1942 and 1943. Anthrax-laced cattle cakes were prepared and stockpiled, also for retaliation.

1.3.5
From the End of World War II to the 1980 – the Great Bioweapons Programs

The United States continued research on various offensive biological weapons during the 1950s and 1960s [13, 15]. From 1951 to 1954, harmless organisms were set free at both coasts of the United States to demonstrate the vulnerability of American cities to biological attacks. This weakness was tested again in 1966 when a test substance was released in the New York City subway system.

During the Vietnam War, Viet Cong guerrillas used needle-sharp punji sticks dipped in feces to cause severe infections after an enemy soldier had been stabbed. In 1979, an accidental release of anthrax from a weapons facility in Sverdlovsk, USSR, killed at least 66 people. The Russian government claimed these deaths were due to infected meat, and maintained this position until 1992, when Russian President Boris Yeltsin finally admitted the accident [16].

1.3.6
From the 1980 Up Today – the Emerging of Bioterrorism

Several countries have continued offensive biological weapons research and use [17]. Additionally, since the 1980s, terrorist organizations have become appliers of biological agents [18, 19]. Usually, these cases amount only to hoaxes. However, exceptions have been noted (Table 1.4) and the range of diseases caused by biological agents and their bioterroristic potential is discussed extensively [27].

1.3.7
Conclusions and Outlook

We have discussed why we still fear the use of biological agents. Deadly pandemics and epidemics in the history of human kind have led to devastating effects in the economy and society. With the rise of gene- and biotechnology new scenarios for the possible use of biological agents have plagued the world. The understanding of the mechanism of action of biological agents as possible biological weapons is closely linked to the breakthrough in science and industrial manufacturing over the last 60 years. From a historical point of view it is important to mark/flag and understand the leaps – our understanding of genetics and the possibility of designing new biological warfare agents marks a new phase (Figure 1.10). Therefore, it is likely that future breakthroughs in natural science, especially in gene- and biotechnology, could lead to further leaps in the development of new biological agents tailored for specific missions.

Table 1.4 Examples of the emergence of bioterrorism.

Time	Event
Autumn 1984	Followers of the Bhagwan Shree Rajneesh contaminated restaurant salad bars with *Salmonella* in Oregon; 751 people were intentionally infected with the agent, which causes food poisoning
1985	Iraq began an offensive biological weapons program, producing anthrax, botulinum toxin, and aflatoxin. Iraq disclosed that it had bombs, Scud missiles, 122-mm rockets, and artillery shells armed with the B-agents. They also had spray tanks fitted to aircraft that could distribute agents over a specific target
1994	A Japanese sect of the Aum Shinrikyo cult attempted an aerosolized (sprayed into the air) release of anthrax from the tops of buildings in Tokyo
1995	Two members of a Minnesota militia group were convicted of possession of ricin, which they had produced themselves for use in retaliation against local government officials
2001	Anthrax was delivered by mail to US media and government offices. There were four deaths
2002	Six terrorist suspects were arrested in Manchester, England; their apartment was serving as a ''ricin laboratory''
2003	British police raided two residences around London and found traces of ricin, which led to an investigation of a possible Chechen separatist plan to attack the Russian embassy with the toxin; several arrests were made
2004	Three US Senate office buildings were closed after the toxin ricin was found in mailrooms that served the then Senate Majority Leader Bill Frist's office

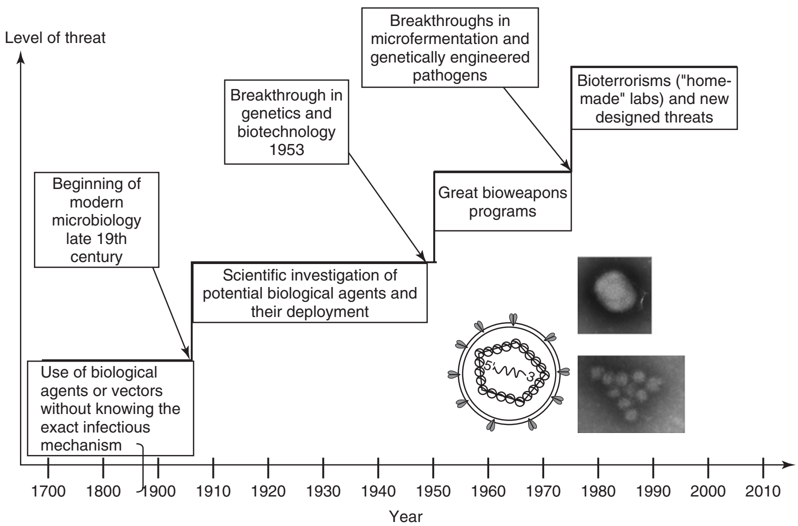

Figure 1.10 Breakthroughs in natural science and industrial development led to important leaps in the development and deployment of biological agents in human history.

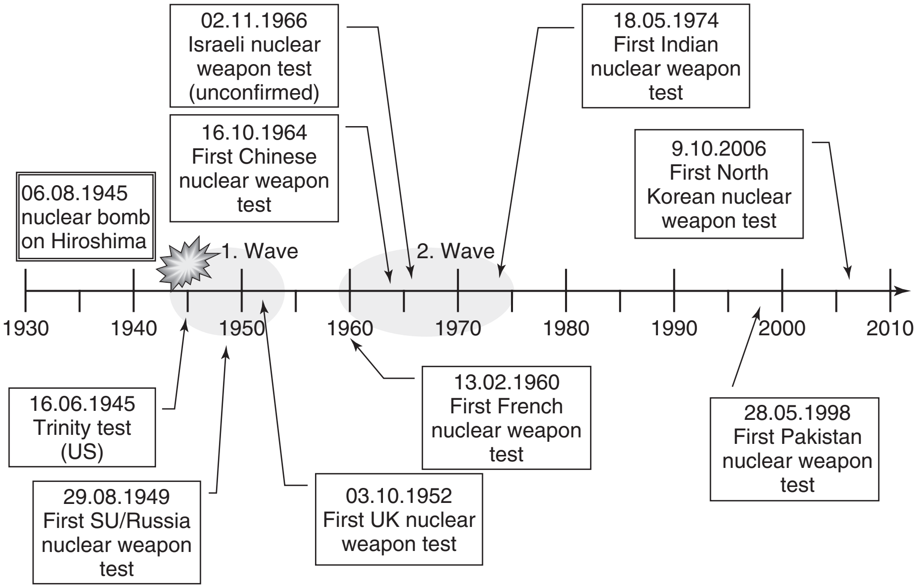

Figure 1.11 Timeline of the nuclear age.

1.4 Introduction to Radiological and Nuclear Warfare

Here we provide a brief survey of the development of radiological and nuclear warfare, from the discovery of nuclear fission, through the development of the first nuclear bomb and the nuclear arms race, to today's nuclear proliferation and threats caused by radiological warfare devices (Figure 1.11). Our objectives are to (i) sum up key developments in nuclear warfare, (ii) provide background information on nuclear armament (e.g., political aspects, nuclear doctrines, and operational aspects), (iii) introduce constitutive stages of nuclear armament, (iv) analyze the historical tendency of nuclear warfare, and (v) explain basic ideas of radiological warfare.

Before we start our tour through the history of nuclear and radiological warfare we need to set the terminology employed by defining often used basic terms:

- **Nuclear warfare**: a military conflict or political strategy in which nuclear weapons are used.
- **Nuclear weapon**: An explosive device that derives its destructive force from nuclear reactions, either fission or a combination of fission and fusion. Nuclear weapons are considered weapons of mass destruction, and their

use and control has been a major aspect of international policy since their debut.

- **Thermonuclear weapon**: A nuclear weapon that derives its energy from the fusion of hydrogen. Also known as a *hydrogen weapon*.
- **Radiological warfare**: any form of warfare involving deliberate radiation poisoning, without relying on nuclear fission or nuclear fusion.
- **Radiological weapon**: any weapon that is designed to spread radioactive material with the intent to kill and cause disruption upon an area (e.g., city).
- **Nuclear fission**: A nuclear reaction in which the nucleus of an atom splits into smaller parts, often producing free neutrons and lighter nuclei, which may eventually produce photons (in the form of gamma rays). Fission of heavy elements is an exothermic reaction that can release large amounts of energy both as electromagnetic radiation and as kinetic energy of the fragments
- **Nuclear fusion**: The process by which multiple like-charged atomic nuclei join together to form a heavier nucleus. It is accompanied by the release or absorption of energy, which allows matter to enter a plasma state. The fusion of two nuclei with lower mass than iron generally releases energy, while the fusion of nuclei heavier than iron absorbs energy.

1.4.1 Discovery of Nuclear Fission

The history of nuclear weapons started with the discovery of its fundamental physical mechanisms, nuclear fission and nuclear fusion. In the first three decades of the twentieth century fundamental developments in our understanding of the nature of atoms, including radioactivity, revolutionized physics. In 1932 John Cockcroft and Ernest Walton ''split the atom'' for the first time by bombarding lithium with protons. In 1934 Enrico Fermi and his colleagues in Rome studied the results of bombarding uranium with neutrons. Inspired by Fermi's results Lise Meitner, Otto Hahn, and Fritz Strassmann performed similar experiments in Germany. In December 1938 Hahn and Strassmann submitted a manuscript to *Naturwissenschaften* reporting that they detected the element barium after bombarding uranium with neutrons. Lise Meitner and Otto Robert Frisch correctly interpreted these results as being nuclear fission [20].

The news on nuclear fission was spread further during the Fifth Washington Conference on Theoretical Physics in January 1939, which fostered many more experimental demonstrations. Frédéric Joliot-Curie's team in Paris discovered that secondary neutrons are released during uranium fission, thus making a nuclear chain-reaction feasible. With the news of fission neutrons, Leo Szilárd immediately understood the possibility of a nuclear chain reaction using uranium. In the summer of 1939, Fermi and Szilard proposed the idea of a nuclear reactor (pile) to mediate this process. The pile would use natural uranium as fuel, and graphite as the moderator of neutron energy. At that time scientists in America as well as in Europe were well aware of the potential of utilizing nuclear fission as a powerful weapon, but no one was quite sure how it could be done.

Leo Szilárd (11 February 1898 to 30 May 1964) was a Hungarian physicist who conceived the nuclear chain reaction and worked on the Manhattan Project. During 1936, he assigned the chain-reaction patent to the British Admiralty to ensure its secrecy (GB patent 630726). Szilárd was also the co-holder, with Enrico Fermi, of the patent on the nuclear reactor (US Patent 2,708,656).

Hans Albrecht Bethe (2 July 1906 to 6 March 2005) was a German–American physicist, and Nobel laureate in physics for his work on the theory of stellar nucleosynthesis. He was head of the Theoretical Division at the secret Los Alamos laboratory developing the first atomic bombs. There he played a key role in calculating the critical mass of the weapons, and carried out theoretical work on the implosion method. Along with Richard Feynman, he developed a formula for calculating the explosive yield of the bomb. During the early 1950s, Bethe also played an important role in the development of the larger hydrogen bomb.

J. Robert Oppenheimer (22 April 1904 to 18 February 1967) was an American theoretical physicist and professor of physics at the University of California, Berkeley. He is best known for his role as the scientific director of the Manhattan Project, the World War II effort to develop the first nuclear weapons at the secret Los Alamos National Laboratory in New Mexico. After the war Oppenheimer was a chief advisor to the newly created United States Atomic Energy Commission and used that position to lobby for international control of nuclear power and to avert the nuclear arms race with the Soviet Union.

At the Cavendish Laboratory, at the University of Cambridge, Mark Oliphant observed the fusion of hydrogen isotopes for the first time in 1932. In 1939 Hans Bethe theorized about nuclear fusion and worked out the main cycle of nuclear fusion in stars. Bethe suggested that much of the energy output of the Sun and other stars results from reactions in which four hydrogen nuclei unite to form one helium nucleus while releasing a large amount of energy.

Later research proved that fusion reactions can indeed occur, but only at many millions of degrees kelvin when the electrostatic forces of repulsion that result from the presence of positive electric charges in both nuclei can be overcome so that the nuclear forces of attraction can perform a fusion. Such high temperatures, however, only occur in stars or in uncontrolled nuclear chain reactions.

1.4.2
Manhattan Project – Development of the First Fission Weapons

Up to the beginning of World War II many key discoveries in nuclear physics and nuclear chemistry were made by German scientists. Owing to this fact, there was concern among scientists in the Allied nations that Germany might have a project to develop fission-based weapons. In March 1940 Otto Frisch and Rudolf Peierls, two exiled German scientists living in Britain, reported in their famous Frisch–Peierls memorandum that if uranium-235 is completely separated from uranium-238 there is no need to slow the neutrons down, so no moderator was required. Consequently, in Great Britain a top-secret committee of experts (later known as the *MAUD* [1] Committee) was formed to investigate the feasibility of an atomic bomb. The MAUD report led to the ‘‘Tube Alloys Project,’’ the first organized research on nuclear weapons. The ‘‘Tube Alloys Project’’ remained as the leading nuclear project until the start of the ‘‘Manhattan Project’’ in 1942.

The USA had started investigations into nuclear weapons with the Uranium Committee in 1939. Owing to MAUD reports and first results of the ‘‘Tube Alloys Project,’’ which indicated that a fission weapon could be accomplished within a few years, in 1942 the USA reorganized its nuclear research under the control of the US Army as the ‘‘Manhattan Project’’ (Figure 1.12). In August 1943 Winston

Figure 1.12 Major research sites of the Manhattan Project.

Churchill and Franklin D. Roosevelt agreed on cooperation on nuclear research by signing the Quebec Agreement. The United Kingdom handed over all of its material to the United States and, in return, received all the copies of the American progress reports to the president. The British atomic research was subsumed then into the ''Manhattan Project'' until after the war, and a large team of British and Canadian scientists moved to the United States.

The Manhattan Project encompassed research activities at over 30 sites across the United States (Figure 1.12), Canada, and the United Kingdom. The three primary research and production sites of the project were the plutonium-production facility at what is now the Hanford Nuclear Reservation, Hanford (WA), the uranium-enrichment facilities at Oak Ridge (TN), and the weapons research and design laboratory now known as Los Alamos National Laboratory, Los Alamos (NM). The Manhattan Project resolved its first key scientific hurdle on 2 December 1942, when a team at the University of Chicago was able to initiate the first artificial self-sustaining nuclear chain reaction. Using these designs, massive reactors was secretly created at the Hanford Site to transform uranium 238 (^{238}U) into plutonium 239 (^{239}Pu). Plutonium-239 is a relatively stable element that does not exist in nature and is also fissible.

Another key scientific hurdle for the Manhattan Project was the production and purification of ^{235}U. Some 99.3% of natural uranium is ^{238}U, which cannot be used for a fission weapon as it absorbs neutrons and does not split. Two methods were developed to overcome this problem, electromagnetic separation and gaseous diffusion. Both methods separate isotopes based on their different weights. For the large-scale production and purification another secret site was erected at Oak ridge (TN).

The highly purified ^{235}U was used to build a gun-type fission weapon, called ''*Little Boy*.'' The gun-type design consists of a mass of ^{235}U, which is fired down a gun barrel like tube into another mass of ^{235}U. In the moment of the impact both mass rapidly create the critical mass of ^{235}U, resulting in a nuclear explosion. Even though the fundamental assumptions were verified in extensive laboratory work, no system level test was carried out as the design was so certain to work. In addition, the bomb that was dropped on Hiroshima used all the existing highly purified ^{235}U, and so there was no ^{235}U available for such a system level test.

Trinity was the first test of technology for a nuclear weapon (Figure 1.13). It was conducted by the United States on 16 July 1945, on the White Sands Proving Ground. Trinity was a test of an implosion-design plutonium device. The Trinity detonation was equivalent to the explosion of around 20 kt of TNT (trinitrotoluene) and is usually considered the beginning of the Nuclear Age.

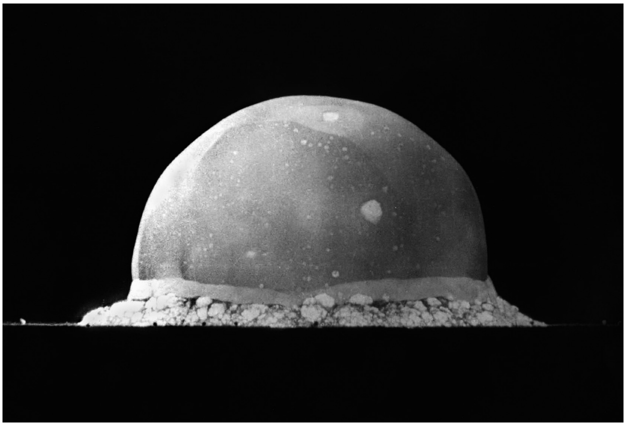

Figure 1.13 Trinity explosion 0.016 s after detonation. The fireball is about 200 m wide. Image is public domain.

In 1943–1944, work with regard to a plutonium-based bomb focused on a gun-type design called "*Thin Man*." In April 1944 the research laboratory at Los Alamos received the first sample of Hanford-produced plutonium. Within two weeks, the research team discovered a problem: reactor-bred plutonium was far less isotopically pure than cyclotron-produced plutonium, which made the Hanford plutonium unsuitable for use in a gun-type weapon.

This problem was solved by changing to the idea of "implosion," an alternative detonation scheme that had existed for some time at Los Alamos. The implosion design employed chemical explosives to squeeze a sub-critical sphere of fissile material into a smaller and denser form. When the fissile atoms were packed closer together, the rate of neutron capture would increase, and the mass would become a critical mass. The metal needed to travel only very short distances, so the critical mass would be assembled in much less time than it would take to assemble a mass by a bullet impacting a target. Because of the complexity of an implosion-type weapon, it was decided that, despite the waste of fissile material, an initial test would be required. The first nuclear test took place on 16 July 1945 on White Sands Proving Ground under the code name "Trinity" (Figure 1.13).

Use of nuclear weapon: In the history of warfare, only two nuclear weapons have been detonated as part of military operations. The first was a uranium gun-type device code-named "Little Boy," which was dropped by the United States on the Japanese city of Hiroshima on the morning of 6 August 1945 (Figure 1.14). The second was detonated three days later when the United States dropped a plutonium implosion-type device code-named "Fat Man" on the city of Nagasaki, Japan.

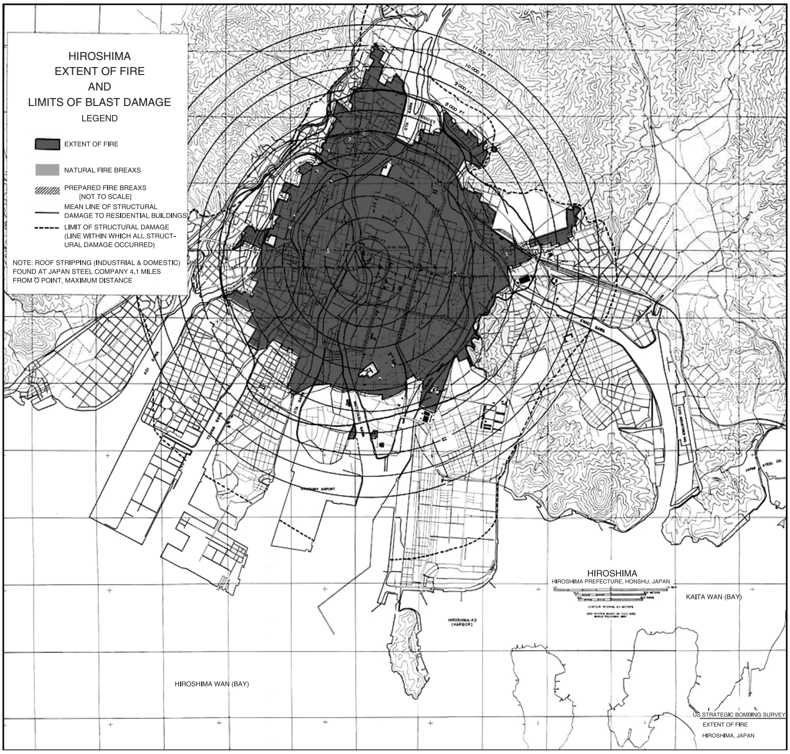

Figure 1.14 Impact of "Little Boy." Image is public domain.

On 10–11 May 1945 the Target Committee at Los Alamos recommended Kyoto, Hiroshima, Yokohama, and the arsenal at Kokura as possible targets. On 6 August 1945, a uranium-based weapon, "Little Boy," was dropped on the Japanese city of Hiroshima (Figure 1.14). Three days later, a plutonium-based weapon, "Fat Man," was dropped onto the city of Nagasaki. At least 100 000 Japanese were killed immediately by the heat, radiation, and blast effects of the nuclear weapons. President Truman's statement that the USA would continue with extensive use of nuclear weapons if Japan did not surrender immediately was in fact a bluff, as the USA had only one remaining completed uranium-gun type bomb.

On 1 January 1947 the Manhattan Program was turned over to the United States Atomic Energy Commission by the Atomic Energy Act of 1946. The Atomic Energy Act broke the partnership of the USA with the United Kingdom and Canada, which has been formed for the Manhattan program, and prevented the passage of any further information regarding nuclear weapons to them. It also ruled that nuclear weapon development and nuclear power management would be under civilian control.

1.4.3
Nuclear Arms Race

The Soviet Union was not invited join the Manhattan Program partnership and to share in the newly developed nuclear weapons. During World War II, however, several volunteer spies involved with the Manhattan Project passed information to the Soviet Union, and the Soviet nuclear physicist Igor Kurchatov, the appointed director of the Soviet nuclear program, was carefully watching the Allied weapons development. In the years immediately after World War II, the Soviets put their full industrial and manpower capabilities into the development of their own atomic weapons. The initial problem for the Soviets was primarily one of resources – they had not scouted out uranium resources in the Soviet Union and the USA had made deals to monopolize the largest known reserves in the Belgian Congo. In the early years mines in East Germany, Czechoslovakia, Bulgaria, and Poland were used as sources of uranium for the Soviet nuclear program.

Efforts in the nuclear program brought results, when the Soviet Union tested its first fission weapon on 29 August 1949 – years ahead of US predictions. The news of the first Soviet nuclear bomb was announced to the world first by the United States, which had detected the nuclear fallout it generated from its test site in Kazakhstan. The USA was shocked not only by the fast progress of the Soviet nuclear program but also by the fact that they had lost their monopoly on nuclear armament. Now both nations (USA and Soviet Union) faced a nuclear tit-for-tat situation. As a consequence, both started a competition for supremacy in nuclear armament, in which both built up a massive arsenal of nuclear weapons (Figure 1.15).

By the 1950s both the United States and Soviet Union had the power to obliterate the other side. Both sides developed a "second-strike" capability, that is, they could launch a devastating attack even after sustaining a full assault from the other side. This policy was part of what became known as Mutually Assured Destruction (MAD): both sides knew that any attack upon the other would be suicidal, and thus would refrain from attack.

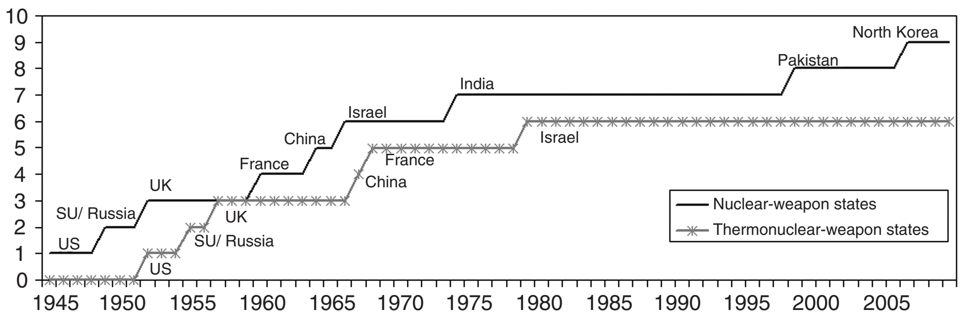

Figure 1.15 Timeline of states with a nuclear arsenal.

The third nation that developed nuclear weapon was the United Kingdom. The US Atomic Energy Act of 1946 prevented the passage of nuclear related information to the United Kingdom. Owing to its involvement in the Manhattan Program the UK had knowledge in some areas. The British nuclear program developed a modified version of the ''Fat Man'' plutonium based implosion type bomb. The British nuclear bomb was successfully tested in Operation Hurricane in Australia on 3 October 1952 (Table 1.5).

During the 1950s all three nuclear nations (USA, Soviet Union, and UK) worked on improving their weapon design as well as the development of the more powerful thermonuclear weapons or so-called ''hydrogen bombs.'' Finally, the initial Anglo-American cooperation on nuclear weapons was restored by the 1958 US-UK Mutual Defense Agreement. As a result of this and the Polaris Sales Agreement, the United Kingdom has bought United States designs for submarine missiles and fitted its own warheads. This first wave of nuclear armament was characterized by competition between the two post World War II superpowers (USA and Soviet Union). The UK participated in this first wave as a spin-off of the Manhattan Project and due to its relationship with the USA.

The nature of this first nuclear wave, with the establishment of superpower nations, told other nations that building nuclear weapons, particular hydrogen bombs, is a form of increasing national self-expression. As a result several nations initiated their own nuclear programs and started a second wave of nuclear armament (Figure 1.15). In the 1950s the French Republic started a civil nuclear research program, which gained plutonium as a by-product. In 1965 a secret Committee for Military applications of Atomic Energy was formed. Under the presidency of Charles de Gaulle the final decision to build a nuclear bomb was taken in 1958. A

Table 1.5 Usage of nuclear weapons and first nuclear tests by known nuclear countries.

Country	Date of first nuclear weapon test	Date of first hydrogen weapon test	Date of usage of nuclear weapon
USA	16 July 1945 Trinity, first ever nuclear explosion	1 November 1952	6 August 1945 ''Little Boy'' on Hiroshima; first usage of nuclear weapon 9 August 1945 ''Fat Man'' on Nagasaki
Soviet Union/Russia	29 August 1949	22 November 1955	–
UK	3 October 1952	15 May 1957	–
France	13 February 1960	28 August 1968	–
China	16 October 1964	17 June 1967	–
India	18 May 1974	–	–
Pakistan	28 May 1998	–	–
North Korea	9 October 2006	–	–

successful test of a French nuclear bomb took place on 13 February 1960 and then on 28 August 1968 a hydrogen weapon was tested. Since then France has improved and maintained its own nuclear capability. China followed a path that is in some ways similar to the French nuclear program. In 1953 China started nuclear research under the umbrella of producing civilian nuclear energy. The Chinese program made rapid progress and, consequently, the first nuclear weapon was tested on 16 October 1964, followed by a hydrogen bomb on 17 June 1967 (Table 1.5).

Owing to intelligence reports Israel joined the group of nuclear weapon nations in 1966 and built thermonuclear weapons in the 1980s. Israel has never officially confirmed or denied that it possesses nuclear weapons, even though the existence of their Dimona nuclear facility was confirmed by the dissident Mordechai Vanunu in 1986. In addition, Israel never performed a full system test, which would have been detected by other nations. The last nation in the second wave of nuclear armament is India. It conducted an underground nuclear test, at Pokharan in the Rajasthan desert, code named the "Smiling Buddha." The government claims it was a peaceful test but it is in fact part of an accelerated weapons program.

The third wave of nuclear armament started at the end of the cold war and is characterized by the proliferation of nuclear weapons among lesser powers and for reasons other than the rivalry between the superpowers USA and the Soviet Union. Owing to competition between India and Pakistan and the success of the Indian nuclear program Pakistan started its own nuclear program. On 28 May 1998, after a series of nuclear tests in India, Pakistan joined the group of nuclear nations with an underground test of fission devices. The intense nuclear testing of nuclear weapons gave rise to concerns that they would use such weapons on each other.

In 2003 North Korea announced that it had performed several nuclear tests but they were never officially confirmed by experts. The first confirmed detonation of a nuclear weapon by the Democratic People's Republic of Korea took place on 9 October 2006.

Tsar Bomba – the Largest Nuclear Detonation

On 30 October 1961 the Soviet Union tested the AN602 hydrogen bomb (nicknamed Tsar Bomba). The Tsar Bomba is the largest, most powerful nuclear weapon ever detonated, and currently the most powerful explosive ever created by humanity. The original US estimate of the yield was 57 Mt, but since 1991 all Russian sources have stated its yield as 50 Mt. The fireball was 8 km in diameter, touched the ground, and reached nearly as high as the altitude of the release plane. The heat from the explosion could have caused third degree burns 100 km away from ground zero. The subsequent mushroom cloud was about 64 km high and 40 km wide. The explosion could be seen and felt almost 1000 km from ground zero in Finland, breaking windows there and in Sweden. Atmospheric focusing caused blast damage up to 1000 km away.

The seismic shock created by the detonation was measurable even on its third passage around the Earth. Its Richter magnitude was about 5–5.25. The energy yield was around 7.1 on the Richter scale, but since the bomb was detonated in the air, rather than underground, most of the energy was not converted into seismic waves.

The dates of the first successful nuclear weapon test or the first test of a hydrogen weapon provides us with only one aspect of the nuclear arms race. Other aspects are the reasons for the nuclear weapon programs. As discussed above, the US Manhattan Program was established to investigate the general development of a new weapon technology and to obtain the nuclear weapon before Nazi Germany in World War II. The Soviet Union started their nuclear program to keep up with the other major post-World War II power, the USA. Great Britain and France have been powerful counties in Europe for centuries. Consequently, they saw a possibility to maintain this status post-World War II by building up nuclear capabilities. China's reasons were similar, as China wanted to rebuild its status as a ruling nation in Asia. In addition, those programs were part of the rising rivalry between the so-called western (USA) and communist or eastern (Soviet Union) blocks. The **Treaty on the Non-Proliferation of Nuclear Weapons** (NPT, nonproliferation treaty) of 1968 acknowledged the USA, Soviet Union, Great Britain, France, and China officially as nuclear states. The NPT tried to conserve this status as the five official nuclear states agreed not to transfer explosive devices or knowledge of their construction and the remaining member-states agreed not to acquire nuclear weapons. As evidence the official nuclear states are also permanent members of the United Nations Security Council (UNSC).

From this situation, less powerful nations draw the conclusion that the ownership of nuclear weapons makes a country more accepted and respected. As a consequence they saw nuclear armament as way of increasing the national self-expression. Israel started its nuclear weapon program to obtain a powerful option in the wars and competition with its Arab neighbors. At a time when nations with an industry capable of building and operating nuclear power plants gave up any plans for nuclear armament India and Pakistan continued their nuclear program. Since Pakistan has separated from India both nations compete with each other. Several times, disputes have come close to ending in war. Both nations believed that a nuclear arsenal would give them more independence from neighboring nations and more influence among "important nations." The last examples of such nuclear programs are North Korea, Iraq, and Iran. Iraq had to stop its nuclear program after the war with Kuwait. In 2008 North Korea demonstrated the status of their nuclear program by a nuclear test explosion. Officially, Iran declares that its nuclear program is a civil power generation program. However, there are concerns that Iran will build up a nuclear arsenal to counter Israel and to warn the USA.

A third aspect in analyzing the history of nuclear armament is the size of nuclear stockpiles (Figure 1.16). If we compare nuclear stockpiles we see that at each

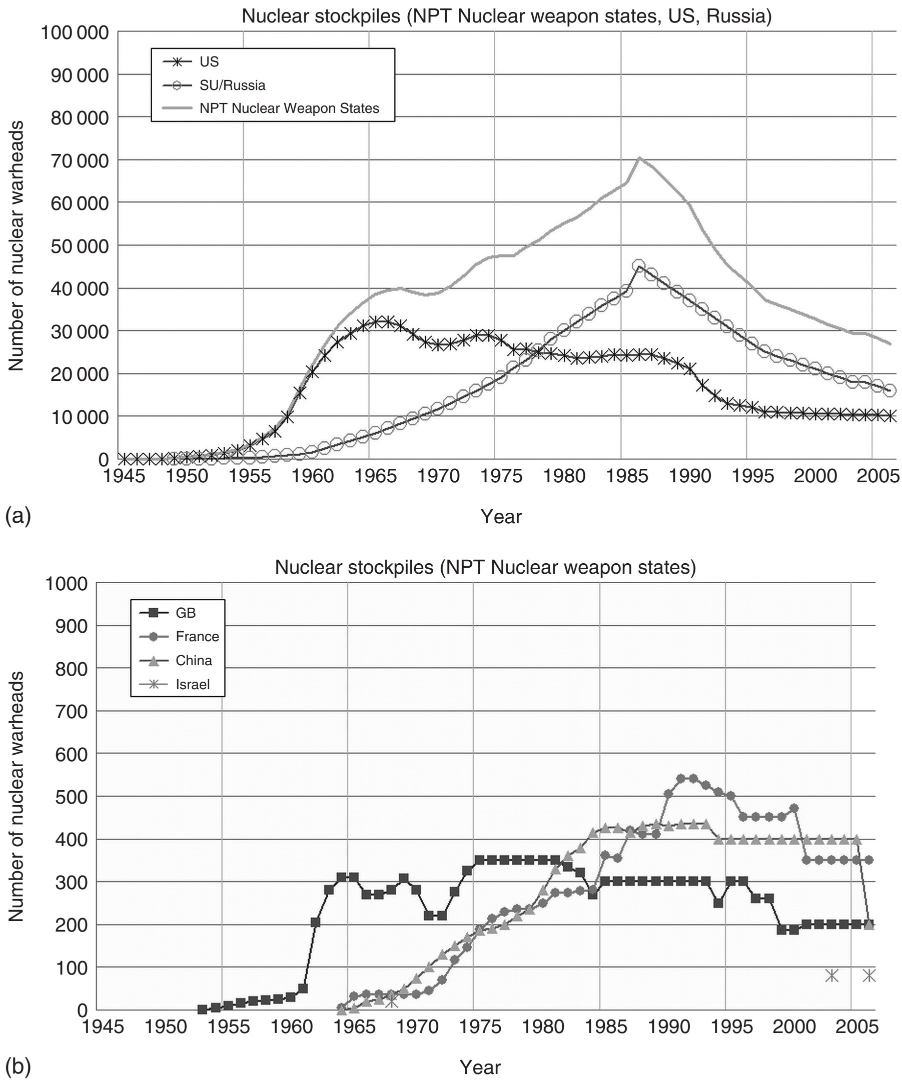

Figure 1.16 Nuclear stockpiles of nuclear weapon states: (a) nuclear stockpiles of USA and Soviet Union/Russia; (b) nuclear stockpiles of other nuclear states.

point in history more than 95% of nuclear warheads worldwide were owned by the USA and Soviet Union/Russia. During the first decade of the nuclear age the USA built up to 30 000 nuclear warheads. Since then the USA has improved its nuclear capability by modernization and has continuously decreased the number of warheads. Owing to problems accessing uranium, the Soviet Union needed two decades to reach the USA stockpile. The Soviet program continued for another decade to build more nuclear warheads. In 1986, the USA and Soviet Union owned more warheads than are needed to destroy the Earth several times over. This nuclear arsenal encompassed a mix of strategic as well as medium- and short-range tactical weapons. Owing to bilateral treaties on the reduction of nuclear arms both nations removed tactical nuclear weapons and reduced the number of warheads to approximately 10 000 each (9400 USA and 13 000 Russia) in 2009. The development of the nuclear stockpile of all other nuclear nations (Figure 1.16b) shows a different tendency. These nations processed a certain number of warheads within a decade and have maintained this number since then. Owing to the small number of warheads (less than 400) it is widely assumed that these arsenals consist of strategic warheads only.

If we compare the Manhattan Program with all other successful nuclear programs we see that the major logistical and technical challenges of nuclear weapon programs are:

- access to sources of uranium,
- production and purification of $^{235}U/^{239}Pu$,
- weapon design.

As most parts of the first two challenges also occur in programs that develop nuclear power systems, any kind of nuclear program carries the danger of providing key knowledge towards a nuclear weapon program.

What is known as the *nuclear arms race* shows us that there are three constitutive stages of nuclear weapons (Figure 1.17 and Table 1.5):

- development (and testing) of a fission weapon,
- development (and testing) of fusion (thermonuclear) weapon,
- usage of nuclear weapon (only the USA has reached this stage).

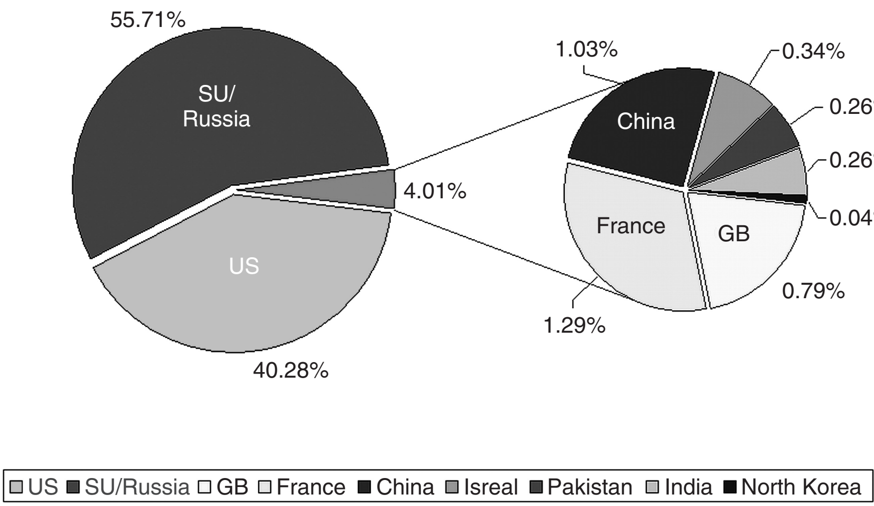

Figure 1.17 Nuclear stockpiles in 2009 [21].

1.4.4
Status of World Nuclear Forces

In each country, the exact number of nuclear assets as well as the current status is a closely held national secret. Despite this limitation, publicly available information and occasional leaks make it possible to estimate the size of the nuclear weapon stockpile (Table 1.6). Those estimates are regularly reported in the *Nuclear Notebook in the Bulletin of the Atomic Scientists* [21] and the nuclear appendix in the *SIPRI Yearbook* [22]. In 2009, approximately two decades after the cold war ended, the Stockholm International Peace Research Institute (SIPRI) reported that the world's combined stockpile of nuclear warheads remained at the high level of more than 23 300. SIPRI considered more than 8190 warheads operational, of which approximately 2200 US and Russian warheads are on high alert, for example, ready for use on short notice.

Owing to the Mutually Assured Destruction (MAD) policy approximately 96% of all nuclear warheads belong to the nuclear arsenal of Russia (55.71%) and the USA (40.28%). All other nuclear nations add up to only 4% (Figure 1.17).

In the current political situation most nations, including Russia and USA, want to avoid any kind of nuclear war. As a consequence even a country that owns a limited number of warheads (like North Korea, with less than ten warheads) poses a significant nuclear threat.

1.4.5
Radiological Warfare and Nuclear Terrorism

In addition to the military use of nuclear weapons, experts have been discussing the possibility that non-state terrorist groups could employ nuclear devices since the 1970s. In 1975 *The Economist* warned that a nuclear bomb can be built out of a few kilograms of plutonium [23]. Since by the mid-1980s power stations turned out

Table 1.6 Status of world nuclear forces[a] [21].

Country	Total nuclear inventory
Russia	13 000
United States	9400
France	300
China	240
United Kingdom	185
Israel	80
Pakistan	60
India	60
North Korea	<10

[a] All numbers are estimates.

many tons of plutonium that each year was transferred from one plant to another, as it proceeded through the fuel cycle, the dangers of robbery in transit became evident. In fact, though, there was a perception in Washington that the value of what is called ''*special nuclear material*'' – plutonium or highly enriched uranium – was so enormous that strict financial accountability of the private contractors who dealt with it would be enough to protect it from falling into the wrong hands. But it has since been revealed that the physical safeguarding of bomb-grade material against theft was almost scandalously neglected. The public focus on this issue changed after an NBC aired Special Bulletin, a television dramatization of a nuclear terrorist attack on the United States. As a result of the public discussion in 1986 a private panel of experts known as the *International Task Force on the Prevention of Terrorism* released a report urging all nuclear-armed states to beware the dangers of terrorism. The experts warned that the probability of nuclear terrorism is increasing and the consequences for urban and industrial societies could be catastrophic.

A report published in 2004 by the National Commission on Terrorist Attacks upon the United States showed how real the threat of nuclear terrorism became over the years [24]. In the report the Commission released information on an unsuccessful attempt by al-Qaeda to purchase uranium in 1994 and that al-Qaeda continues to pursue its strategic objective of obtaining a nuclear weapon. A May 2004 report [25] by Harvard University's Project on Managing the Atom found that a nuclear attack ''would be among the most difficult types of attacks for terrorists to accomplish,'' but that with the necessary fissile materials, ''a capable and well-organized terrorist group plausibly could make, deliver, and detonate at least a crude nuclear bomb capable of incinerating the heart of any major city in the world.''

Nuclear terrorism employs nuclear weapons, which release energy in a huge nuclear explosion. As we have learned through the review of the history of nuclear warfare the design of such nuclear weapons belongs to a highly sophisticated level of engineering science.

In contrast a terrorist may use a radiological dispersal device (RDD) that simply scatters radioactive material. Evidently, the design of such a RDD is much easier than building a nuclear weapon. The main physical effect of radiological dispersal is the contamination of an area. Warfare involving deliberate radiation poisoning, without relying on nuclear fission or nuclear fusion, is summarized under the term radiological warfare. Consequently, any criminal and terrorist action using radiological dispersal can be called *radiological terrorism*. The fear of radiological terrorism arose in conjunction with the increasing use of radioactive isotopes in civil applications. For example, cesium-137, which is used in external beam radiation devices to treat cancers and equipment to monitor wells for oil, and cobalt-60, which is used in industrial radiography and cancer therapy, might be used as dispersal radioactive material.

The aftermath of several radiological accidents, such as those in Mexico City (1962), Algeria (1978), Morocco (1983), Ciudad Juarez in Mexico (1983), and Goiania in Brazil (1987) demonstrate the endangerment caused by disposed radioactive material. The accident in Goiania was one of the most serious radiological accidents. On 13 September 1987, a shielded, strongly radioactive cesium-137 source was removed from its protective housing in a teletherapy machine in an abandoned clinic in Goiania, Brazil, and subsequently ruptured. Consequently, 93 g of the radioactive cesium chloride salt was dispersed and many people incurred large doses of radiation, due to both external and internal exposure. Four of the casualties ultimately died and 28 people suffered radiation burns. Residences and public places were contaminated. Decontamination necessitated the demolition of seven residences and various other buildings, and the removal of the topsoil from large areas. In total about 3500 m^3 of radioactive waste were generated [26]. Nowadays the media often refer to RDD by the term "*dirty bomb*." This term focuses on a device in which powdered radioisotope surrounds chemical explosive. In fact many terrorist groups probably have the skill and materials to make the explosive part of the device; but it would be somewhat harder for them to obtain the radioactive material and convert it into powdered form. However, we should bear in mind that terrorists could also scatter radioactive material without an explosive.

1.4.6 Conclusions and Outlook

In this subsection we have learned that for the first time in our history we are able to eradicate ourselves. The unleashing of the nuclear power led to catastrophic consequences in Hiroshima and Nagasaki. During the cold war the nuclear arms race between United States and Soviet Union led to each having the power to obliterate the other side. Both sides had a "second-strike" capability, that is, they could launch a devastating attack even after sustaining a full assault from the other side.

Nowadays several other states are trying to enter the exclusive club of nations with nuclear weapons. Furthermore, the danger of nuclear terrorism cannot be denied. The combination of explosive devices with radiological material ("dirty bomb") may not have such apocalyptic consequences as the use of a nuclear bomb, but it could make large areas uninhabitable.

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