Chapter 1

A History of Public Health

INTRODUCTION

History provides a perspective to develop an understanding of health problems of communities and how to cope with them. We see through the eyes of the past how societies conceptualized and dealt with disease. All societies must face the realities of disease and death, and develop concepts and methods to manage them. These coping strategies form part of a worldview associated with a set of cultural or scientific beliefs, which in turn help to determine the curative and preventive approaches to health.

The history of public health is a story of the search for effective means of securing health and preventing disease in the population. Epidemic and endemic infectious disease stimulated thought and innovation in disease prevention on a pragmatic basis, often before the causation was established scientifically. The prevention of disease in populations revolves around defining diseases, measuring their occurrence, and seeking effective interventions.

Public health evolved with trial and error and with expanding scientific medical knowledge, often stimulated by war and natural disasters. The need for organized health services grew as part of the development of community life, and in particular, urbanization. Religious and societal beliefs influenced approaches to explaining and attempting to control communicable disease by sanitation, town planning, and provision of medical care. Where religious and social systems repressed scientific investigation and spread of knowledge, they were capable of inhibiting development of public health.

Modern society still faces the ancient scourges of malaria, cholera, and plague, as well as the more prominent killers: obesity, cardiovascular disease, mental depression, trauma, and cancer. The advent of AIDS, SARS, avian influenza, and emerging drug-resistant microorganisms forces us to seek new ways of preventing their potentially serious consequences to society. Diseases, natural disasters, and man-made catastrophes including war, terrorism, and genocide are always threats to human civilization. The evolution of public health continues; pathogens change, as do the environment and the host. In order to face challenges ahead, it is important to have an understanding of the past.

PREHISTORIC SOCIETIES

Earth is considered to be 4.5 billion years old, with the earliest stone tools dating from 2.5 million years BCE representing the presence of antecedents of man. *Homo erectus* lived

from 1.5 million to 500,000 years ago and *Homo sapiens Neanderthalensis* at about 110,000 BCE. The Paleolithic Age is the earliest stage of man's development where organized societal structures are known to have existed. These social structures consisted of people living in bands which survived by hunting and gathering food. There is evidence of use of fire going back some 230,000 years, and increasing sophistication of stone tools, jewelry, cave paintings, and religious symbols during this period. Modern man evolved from *Homo sapiens,* probably originating in Africa and the Middle East about 90,000 years ago, and appearing in Europe during the Ice Age period from 40,000–35,000 BCE. During this time, man spread over all major land masses following the retreating glaciers of the last Ice Age at 11,000–8000 BCE.

A Mesolithic Age or transitional phase of evolution from hunter-gatherer societies into the Neolithic Age of food-raising societies occurred at different periods in various parts of the world, first in the Middle East from 9000 to 8000 BCE onward, reaching Europe about 3000 BCE. The change from hunting, fishing, and gathering modes of survival to agriculture was first evidenced by domestication of animals and then growing of wheat, barley, corn, root crops, and vegetables. Associated skills of food storage and cooking, pottery, basket weaving, ovens, smelting, trade, and other skills led to improved survival techniques and population growth gradually spread throughout the world.

Communal habitation became essential to adaptation to changing environmental conditions and hazards allowing population growth and geographic expansion. At each stage of human biological, technological, and social evolution, man coexisted with diseases associated with the environment and living patterns, seeking herbal and mystical treatments for the maladies. Man called on the supernatural and magic to appease these forces and prevent plagues, famines, and disasters. Shamans or witch doctors attempted to remove harm by magical or religious practices along with herbal treatments acquired through trial and error.

Nutrition and exposure to communicable disease changed as mankind evolved. Social organization included tools and skills for hunting, clothing, shelter, fire for warmth and cooking of food for use and storage, burial of the dead, and removal of waste products from living areas. Adaptation of human society to the environment has been and remains a central issue in health to the present time. This is a recurrent theme in the development of public health, facing daunting new challenges of adaptation and balance with the environment.

THE ANCIENT WORLD

Development of agriculture served growing populations unable to exist solely from hunting, stimulating the organization of more complex societies able to share in production and in irrigation systems. Division of labor, trade, commerce, and government were associated with development of urban societies. Growth of population and communal living led to improved standards of living but also created new health hazards including spread of diseases. As in our time, these challenges required community action to prevent disease and promote survival.

Eastern societies were the birthplace of world civilization. Empirical and religious traditions were mixed. Superstition and shamanism coexisted with practical knowledge of herbal medicines, midwifery, management of wounds or broken bones, and trepanation to remove "evil spirits" that resulted from blood clots inside the skull. All were part of communal life with variations in historical and cultural development. The advent of writing led to medical documentation. Requirements of medical conduct were spelled out as part of the general legal Code of Hammurabi in Mesopotamia (circa 1700 BCE). This included regulation of physician fees and punishment for failure and set a legal base for the secular practice of medicine. Many of the main traditions of medicine were those based on magic or that derived from religion. Often medical practice was based on belief in the supernatural, and healers were believed to have a religious calling. Training of medical practitioners, regulation of their practice, and ethical standards evolved in a number of ancient societies.

Some cultures equated cleanliness with godliness and associated hygiene with religious beliefs and practices. Chinese, Egyptian, Hebrew, Indian, and Incan societies all provided sanitary amenities as part of the religious belief system and took measures to provide water, sewage, and drainage systems. This allowed for successful urban settlement and reinforced the beliefs upon which such practices were based. Personal hygiene was part of religious practice. Technical achievements in providing hygiene at the community level slowly evolved as part of urban society.

Chinese practice in the twenty-first to eleventh centuries BCE included digging of wells for drinking water; from the eleventh to the seventh centuries BCE this included use of protective measures for drinking water and destruction of rats and rabid animals. In the second century BCE, Chinese communities were using sewers and latrines. The basic concept of health was that of countervailing forces between the principles of yin (female) and yang (male), with emphasis on a balanced lifestyle. Medical care emphasized diet, herbal medicine, hygiene, massage, and acupuncture.

Ancient cities in India were planned with building codes, street paving, and covered sewer drains built of bricks and mortar. Indian medicine originated in herbalism associated with the mythical gods. Between 800 and 200 BCE, Ayurvedic medicine developed and with it, medical schools and public hospitals. Between 800 BCE and 400

CE, major texts of medicine and surgery were written. Primarily focused in the Indus Valley, the golden age of ancient Indian medicine began in approximately 800 BCE. Personal hygiene, sanitation, and water supply engineering were emphasized in the laws of Manu. Pioneering physicians, supported by Buddhist kings, developed the use of drugs and surgery, and established schools of medicine and public hospitals as part of state medicine. Indian medicine played a leading role throughout Asia, as did Greek medicine in Europe and the Arab countries. With the Mogul invasion of 600 CE, state support declined, and with it, Indian medicine.

Ancient Egyptian intensive agriculture and irrigation practices were associated with widespread parasitic disease. The cities had stone masonry gutters for drainage, and personal hygiene was highly emphasized. Egyptian medicine developed surgical skills and organization of medical care, including specialization and training that greatly influenced the development of Greek medicine. The Eberus Papyrus, written 3400 years ago, gives an extensive description of Egyptian medical science, including isolation of infected surgical patients.

The Hebrew Mosaic Law of the five Books of Moses (circa 1000 BCE) stressed prevention of disease through regulation of personal and community hygiene, reproductive and maternal health, isolation of lepers and other "unclean conditions," and family and personal sexual conduct as part of religious practice. It also laid a basis for medical and public health jurisprudence. Personal and community responsibility for health included a mandatory day of rest, limits on slavery and guarantees of the rights of slaves and workers, protection of water supplies, sanitation of communities and camps, waste disposal, and food protection, all codified in detailed religious obligations. Food regulation prevented use of diseased or unclean animals, and prescribed methods of slaughter improved the possibility of preservation of the meat. While there was an element of viewing illness as a punishment for sin, there was also an ethical and social stress on the value of human life with an obligation to seek and provide care. The concepts of sanctity of human life (*Pikuah Nefesh*) and improving the quality of life on Earth (*Tikun Olam*) were given overriding religious and social roles in community life. In this tradition, the saving of a single human life was considered "as if one saved the whole world," with an ethical imperative to achieve a better earthly life for all. The Mosaic Law, which forms the basis for Judaism, Christianity, and Islam, codified health behaviors for the individual and for society, all of which have continued into the modern era as basic concepts in environmental and social hygiene.

In Cretan and Minoan societies, climate and environment were recognized as playing a role in disease causation. Malaria was related to swampy and lowland areas, and prevention involved planning the location of settlements. Ancient Greece placed high emphasis on healthful living habits in terms of personal hygiene, nutrition, physical fitness, and community sanitation. Hippocrates articulated the clinical methods of observation and documentation and a code of ethics of medical practice. He articulated the relationship between disease patterns and the natural environment (Air, Water, and Places) which dominated epidemiologic thinking until the nineteenth century. Preservation of health was seen as a balance of forces: exercise and rest, nutrition and excretion, and recognizing the importance of age and sex variables in health needs. Disease was seen as having natural causation, and medical care was valued, with the city-state providing free medical services for the poor and for slaves. City officials were appointed to look after public drains and water supply, providing organized sanitary and public health services. Hippocrates gave medicine both a scientific and ethical spirit lasting to the present time.

Ancient Rome adopted much of the Greek philosophy and experience concerning health matters with high levels of achievement and new innovations in the development of public health. The Romans were extremely skilled in engineering of water supply, sewage and drainage systems, public baths and latrines, town planning, sanitation of military encampments, and medical care. Roman law also regulated businesses and medical practice. The influence of the Roman Empire resulted in the transfer of these ideas throughout much of Europe and the Middle East. Rome itself had access to clean water via 10 aqueducts supplying ample water for the citizens. Rome also built public drains. By the early first century the aqueducts allowed people to have 600–900 liters per person per day of household water from mountains. Marshlands were drained to reduce the malarial threat. Public baths were built to serve the poor, and fountains were built in private homes for the wealthy. Streets were paved, and organized garbage disposal served the cities.

Roman military medicine included well-designed sanitation systems, food supplies, and surgical services. Roman medicine, based on superstition and religious rites, with slaves as physicians, developed from Greek physicians who brought their skills and knowledge to Rome after the destruction of Corinth in 146 BCE. Training as apprentices, Roman physicians achieved a highly respected role in society. Hospitals and municipal doctors were employed by Roman cities to provide free care to the poor and the slaves, but physicians also engaged in private practice, mostly on retainers to families. Occupational health was described with measures to reduce known risks such as lead exposure, particularly in mining. Weights and measures were standardized and supervised. Rome made important contributions to the public health tradition of sanitation, urban planning, and organized medical care. Galen, Rome's leading physician, perpetuated the fame of Hippocrates through his medical writings, basing medical assessment on the four humors of man (sanguine,

phlegmatic, choleric, and melancholic). These ideas dominated European medical thought for nearly 1500 years until the advent of modern science.

THE EARLY MEDIEVAL PERIOD (FIFTH TO TENTH CENTURIES CE)

The Roman Empire disappeared as an organized entity following the sacking of Rome in the fifth century CE. The eastern empire survived in Constantinople, with a highly centralized government. Later conquered by the Muslims, it provided continuity for Greek and Roman teachings in health. The western empire integrated Christian and pagan cultures, looking at disease as punishment for sin. Possession by the devil and witchcraft were accepted as causes of disease. Prayer, penitence, and exorcising witches were accepted means of dealing with health problems. The ensuing period of history was dominated in health, as in all other spheres of human life, by the Christian doctrine institutionalized by the Church. The secular political structure was dominated by feudalism and serfdom, associated with a strong military landowning class in Europe.

Church interpretation of disease was related to original or acquired sin. Man's destiny was to suffer on Earth and hope for a better life in heaven. The appropriate intervention in this philosophy was to provide comfort and care through the charity of church institutions. The idea of prevention was seen as interfering with the will of God. Monasteries with well-developed sanitary facilities were located on major travel routes and provided hospices for travelers. The monasteries were the sole centers of learning and for medical care. They emphasized the tradition of care of the sick and the poor as a charitable duty of the righteous and initiated hospitals. These institutions provided care and support for the poor, as well as efforts to cope with epidemic and endemic disease.

Most physicians were monks guided by Church doctrine and ethics. Medical scholarship was based primarily on the teachings of Galen. Women practicing herbal medicine were branded as witches. Education and knowledge were under clerical dominance. Scholasticism, or the study of what was already written, stultified the development of descriptive or experimental science. The largely rural population of the European medieval world lived with poor nutrition, education, housing, sanitary, and hygienic conditions. Endemic and epidemic diseases resulted in high infant, child, and adult mortality. Commonly, 75 percent of newborns died before the age of five. Maternal mortality was high. Leprosy, malaria, measles, and smallpox were established endemic diseases with many other less well-documented infectious diseases.

Between the seventh and tenth centuries, outside the area of Church domination, Muslim medicine flourished under Islamic rule primarily in Persia and later Baghdad and Cairo; Rhazes and Ibn Sinna (Avicenna) translated and adapted ancient Greek and Mosaic teachings, adding clinical skills developed in medical academies and hospitals. Piped water supplies were documented in Cairo in the ninth century. Great medical academies were established, including one in conquered Spain at Cordova. The Cordova Medical Academy was a principal center for medical knowledge and scholarship prior to the expulsion of Muslims and Jews from Spain and the Inquisition. The Academy helped stimulate European medical thinking and the beginnings of western medical science in anatomy, physiology, and descriptive clinical medicine.

THE LATE MEDIEVAL PERIOD (ELEVENTH TO FIFTEENTH CENTURIES)

In the later feudal period, ancient Hebraic and Greco-Roman concepts of health were preserved and flourished in the Muslim Empire. The twelfth-century Jewish philosopher-physician Moses Maimonides, trained in Cordova and expelled to Cairo, helped synthesize Roman, Greek, and Arabic medicine with Mosaic concepts of communicable disease isolation and sanitation.

Monastery hospitals were established between the eighth and twelfth centuries to provide charity and care to ease the suffering of the sick and dying. Monastery hospitals were described in the eleventh century in Russia. Monasteries provided centers of literacy, medical care, and the ethic of caring for the sick patient as an act of charity. The monastery hospitals were gradually supplanted by municipal, voluntary, and guild hospitals developed in the twelfth to sixteenth centuries. By the fifteenth century, Britain had 750 hospitals. Medical care insurance was provided by guilds to its members and their families. Hospitals employed doctors, and the wealthy had access to private doctors.

In the early middle ages, most physicians in Europe were monks, and the medical literature was compiled from ancient sources. In 1131 and 1215, Papal rulings increasingly restricted clerics from doing medical work, thus promoting secular medical practice. In 1224, Emperor Frederick II of Sicily published decrees regulating medical practice, establishing licensing requirements: medical training (3 years of philosophy, 5 years of medicine), 1 year of supervised practice, then examination followed by licensure. Similar ordinances were published in Spain in 1238 and in Germany in 1347.

The Crusades (1096–1270 CE) exposed Europe to Arabic medical concepts, as well as leprosy. The Hospitallers, a religious order of knights, developed hospitals in Rhodes, Malta, and London to serve returning pilgrims and crusaders. The Muslim world had hospitals, such as Al Mansour in Cairo, available to all as a service provided by the government. Growing contact between the Crusaders and the

Muslims through war, conquest, cohabitation, and trade introduced Arabic culture and diseases, and revised ancient knowledge of medicine and hygiene.

Leprosy became a widespread disease in Europe, particularly among the poor, during the early Middle Ages, but the problem was severely accentuated during and following the Crusades, reaching a peak during the thirteenth to fourteenth centuries. Isolation in leprosaria was common. In France alone, there were 2000 leprosaria in the fourteenth century. This disease has caused massive suffering and lingers until now. The development of modern antimicrobials has cured millions of leprosy (Hansen's disease) cases and with early case finding and multidrug therapy, this disease and its disabling and deadly effects are now largely a matter of history.

As rural serfdom and feudalism were declining in Western Europe, cities developed with crowded and unsanitary conditions. Towns and cities developed in Europe with royal charters for self-government, primarily located at the sites of former Roman settlements and at river crossings related to trade routes. The Church provided stability in society, but repressed new ideas and imposed its authority particularly via the Inquisition. Established by Pope Gregory in 1231, the Inquisition was renewed and intensified, especially in Spain in 1478 by Pope Sixtus IV, to exterminate heretics, Jews, and anyone seen as a challenge to the accepted Papal dogmas.

Universities established under royal charters in Paris, Bologna, Padua, Naples, Oxford, Cambridge, and others set the base for scholarship outside the realm of the Church. In the twelfth and thirteenth centuries there was a burst of creativity in Europe, with inventions including the compass, the mechanical clock, the waterwheel, the windmill, and the loom. Physical and intellectual exploration opened up with the travels of Marco Polo and the writings of Thomas Aquinas, Roger Bacon, and Dante. Trade, commerce, and travel flourished.

Medical schools were established in medieval universities in Salerno, Italy, in the tenth century and in universities throughout Europe in the twelfth to fifteenth centuries: in Paris (1110), Bologna (1158), Oxford (1167), Montpellier (1181), Cambridge (1209), Padua (1222), Toulouse (1233), Seville (1254), Prague (1348), Krakow (1364), Vienna (1365), Heidelberg (1386), Glasgow (1451), Basel (1460), and Copenhagen (1478). Physicians, recruited from the new middle class, were trained in scholastic traditions based on translations of Arabic literature and the ancient Roman and Greek texts, mainly Aristotle, Hippocrates, and Galen, but with some more current texts, mainly written by Arab and Jewish physicians.

Growth exacerbated public health problems in the newly walled commercial and industrial towns leading to eventual emergencies, which demanded solution. Crowding, poor nutrition and sanitation, lack of adequate water sources and drainage, unpaved streets, keeping of animals in towns, and lack of organized waste disposal created conditions for widespread infectious diseases. Municipalities developed protected water sites (cisterns, wells, and springs) and public fountains with municipal regulation and supervision. Piped community water supplies were developed in Dublin, Basel, and Bruges (Belgium) in the thirteenth century. Between the eleventh and fifteenth centuries, Novgorod in Russia used clay and wooden pipes for water supplies. Municipal bath houses were available.

Medical care was still largely oriented to symptom relief with few resources to draw upon. Traditional folk medicine survived especially in rural areas, but was suppressed by the Church as witchcraft. Physicians provided services for those able to pay, but medical knowledge was a mix of pragmatism, mysticism, and sheer lack of scientific knowledge. Conditions were ripe for vast epidemics of smallpox, cholera, measles, and other epidemic diseases fanned by the debased conditions of life and vastly destructive warfare raging throughout Europe.

The Black Death (mainly pneumonic and bubonic plague), due to *Yersinia pestis* infection transmitted by fleas on rodents, was brought from the steppes of central Asia to Europe with the Mongol invasions, and then transmitted via extensive trade routes throughout Europe by sea and overland. The Black Death was also introduced to China with Mongol invasions, bringing tremendous slaughter, halving of the population of China between 1200 and 1400 CE. Between the eleventh and thirteenth centuries, during the Mongol–Tatar conquests, many widespread epidemics, including plague, were recorded in Rus (now Russia). The plagues traveled rapidly with armies, caravan traders, and later by shipping as world trade expanded in the fourteenth to fifteenth centuries (see Box 1.1). The plague ravaged most of Europe between 1346 and 1350, killing between 24 and 50 million people; approximately one-third of the population, leaving vast areas of Europe underpopulated. Despite local efforts to prevent disease by quarantine and isolation of the sick, the disease devastated whole communities.

Fear of a new and deadly disease, lack of knowledge, speculation, and rumor led to countermeasures which often exacerbated the spread of epidemics (as occurred in the late twentieth century with the AIDS epidemic). In Western Europe, public and religious ceremonies and burials were promoted, which increased contact with infected persons. The misconception that cats were the cause of plague led to their slaughter, when they could have helped to stem the tide of disease brought by rats and by their fleas to humans. Hygienic practices limited the spread of plague in Jewish ghettoes, leading to the blaming of the plague's spread on the Jews, and widespread massacres, especially in Germany and central Europe.

Box 1.1 "This is the End of the World": The Black Death

"Rumors of a terrible plague supposedly arising in China and spreading through Tartary (Central Asia) to India and Persia, Mesopotamia, Syria, Egypt and all of Asia Minor had reached Europe in 1346. They told of a death toll so devastating that all of India was said to be depopulated, whole territories covered by dead bodies, other areas with no one left alive. As added up by Pope Clement VI at Avignon, the total of reported dead reached 23,840,000. In the absence of a concept of contagion, no serious alarm was felt in Europe until the trading ships brought their black burden of pestilence into Messina while other infected ships from the Levant carried it to Genoa and Venice.

By January 1348 it penetrated France via Marseille, and North Africa via Tunis. Ship-borne along coasts and navigable rivers, it spread westward from Marseille through the ports of Languedoc to Spain and northward up the Rhone to Avignon, where it arrived in March. It reached Narbonne, Montpellier, Carcassone, and Toulouse between February and May, and at the same time in Italy spread to Rome and Florence and their hinterlands. Between June and August it reached Bordeaux, Lyon, and Paris, spread to Burgundy and Normandy into southern England. From Italy during the summer it crossed the Alps into Switzerland and reached eastward to Hungary.

In a given area the plague accomplished its kill within four to six months and then faded, except in the larger cities, where, rooting into the close-quartered population, it abated during the winter, only to appear in spring and rage for another six months."

Source: Tuchman, B. W. A *Distant Mirror: The Calamitous 14th Century*, op cit. page 93.

Seaport cities in the fourteenth century began to apply the biblical injunction to separate lepers by keeping ships coming from places with the plague waiting in remote parts of the harbor, initially for 30 days (*treutina*), then for 40 days (*quarantina*) (Ragusa in 1465 and Venice in 1485), establishing the public health act of quarantine, which on a pragmatic basis was found to reduce the chance of entry of the plague. Towns along major overland trading routes in Russia took measures to restrict movement in homes, streets, and entire towns during epidemics. All over Europe, municipal efforts to enforce isolation broke down as crowds gathered and were uncontrolled by inadequate police forces. In 1630, all officers of the Board of Health of Florence, Italy, were excommunicated because of efforts to prevent spread of the contagion by isolation of cases, thereby interfering with religious ceremonies to assuage God's wrath through appeals to divine providence.

The plague continued to strike with epidemics in London in 1665, Marseille in 1720, Moscow in 1771, and Russia, India, and the Middle East through the nineteenth century. In sixteenth-century Russia, Novgorod banned public funerals during plague epidemics, and in the seventeenth century, Czar Boris Godunov banned trade, prohibited religious and other ceremonies, and instituted quarantine-type measures. Plague continued into the twentieth century (see *The Plague* by Albert Camus) with epidemics in Australia (1900), China (1911), Egypt (1940), and India (1995). The disease is endemic in rodents in many parts of the world, including the United States; however, modern sanitation, pest control, and treatment have greatly reduced the potential for large-scale plague epidemics.

Guilds organized to protect economic interests of traders and skilled craftsmen developed mutual benefit funds to provide financial assistance and other benefits for illness, death, widows and orphans, and medical care, as well as burial benefits for members and their families. The guilds wielded strong political powers during the late middle ages. These brotherhoods provided a tradition later expressed in the mutual benefit or Friendly Societies, sick funds, and insurance for health care based on employment groups. This tradition has continued in western countries, where labor unions are among the leading advocates for the health of workers and their families.

The fourteenth century saw a devastation of the population of Europe by plague, wars, and the breakdown of feudal society. It also set the stage for the agricultural revolution and later the industrial revolution. The period following the Black Death was innovative and dynamic. Lack of farm labor led to innovations in agriculture. Enclosures of common grazing land reduced spread of disease among animals, increased field crop productivity, and improved sheep farming, leading to development of the wool and textile industries and the search for energy sources, industrialization, and international markets.

THE RENAISSANCE (1500–1750)

Commerce, industry, trade, merchant fleets, and voyages of discovery to seek new markets led to the development of a moneyed middle class and wealthy cities. In this period, mines, foundries, and industrial plants flourished, creating new goods and wealth. Partly as a result of the trade generated and the increased movement of goods and people, vast epidemics of syphilis, typhus, smallpox, measles, and the plague continued to spread across Europe. Malaria was still widespread throughout Europe. Rickets, scarlet fever, and scurvy, particularly among sailors, were rampant. Pollution and crowding in industrial areas resulted in centuries-long

epidemics of environmental disease, particularly among the urban working class.

A virulent form of syphilis, allegedly brought back from America by the crews of Columbus, spread rapidly throughout Europe between 1495 and 1503, when it was first described by Fracastorus. Control measures tried in various cities included examination and registration of prostitutes, closure of communal bath houses, isolation in special hospitals, reporting of disease, and expulsion of sick prostitutes or strangers. The disease gradually decreased in virulence, but it remains a major public health problem.

In Russia, Czar Ivan IV (Ivan the Terrible) in the sixteenth century arranged to hire the court physician of Queen Elizabeth I, who brought with him to Moscow a group of physicians and pharmacists to serve the court. The Russian army had a tradition of regimental doctors. In the mid-seventeenth century, the czarist administration developed pharmacies in major centers throughout the country for military and civilian needs, and established a State Pharmacy Department to control pharmacies and medications, education of doctors, military medicine, quarantine, forensic medicine, and medical libraries. Government revenues from manufacturing, sale, and encouragement of vodka provided for these services. Preparation of military doctors (*Lekars*) with 5–7 years of training was instituted in 1654. Hospitals were mainly provided by monasteries, serving both civilian and military needs. In 1682, the first civic hospital was opened in Moscow, and in the same year, two hospitals were opened also in Moscow by the central government for care of patients and training of *Lekars*.

In European countries, growth of cities with industrialization and massive influx of the rural poor brought the focus of public health needs to the doorsteps of municipal governments. The breakdown of feudalism, the decline of the monasteries, and the land enclosures dispossessed the rural poor. Municipal and voluntary organizations increasingly developed hospitals, replacing those previously run by monastic orders. In 1601, the British Elizabethan Poor Laws defined the local parish government as being responsible for the health and social well-being of the poor, a system later brought to the New World by British colonists. Municipal control of sanitation was weak. Each citizen was in theory held responsible for cleaning his part of the street, but hygienic standards were low with animal and human wastes freely accumulating.

During the Renaissance, the sciences of anatomy, physiology, chemistry, microscopy, and clinical medicine opened medicine to a scientific base. Medical schools in universities developed affiliations with hospitals, promoting clinical observation with increasing precision in description of disease. The contagion theory of disease, described in 1546 by Fracastorus and later Paracelsus, including the terms *infection* and *disinfection*, was contrary to the until-then sacrosanct miasma teachings of Galen.

From 1538, parish registers of christenings and burials were published in England as weekly and annual abstracts, known as the *Bills of Mortality*. Beginning in 1629, national annual Bills of Mortality included tabulation of death by cause. On the basis of the Bills of Mortality, novelist Daniel Defoe described the plague epidemic of London of 1665 100 years later.

In 1662, John Graunt in England published *Natural and Political Observations Upon the Bills of Mortality*. He compiled and interpreted mortality figures by inductive reasoning, demonstrating the regularity of certain social and vital phenomena. He showed statistical relationships between mortality and living conditions. Graunt's work was important because it was the first instance of statistical analysis of mortality data, providing a foundation for use of health statistics in the planning of health services. This established the sciences of demography and vital statistics and methods of analysis, providing basic measurements for health status evaluation with mortality rates by age, sex, and location. Also in 1662, William Petty took the first census in Ireland. In addition, he studied statistics on the supply of physicians and hospitals.

Microscopy, developed by Antony van Leeuwenhoek in 1676, provided a method of study of microorganisms. In the seventeenth century, the great medical centers were located in Leyden, Paris, and Montpelier. Bernardino Ramazzini published the first modern comprehensive treatise on occupational diseases in 1700.

In Russia, Peter the Great (1682–1725) initiated political, cultural, and health reforms. He sent young aristocrats to study sciences and technology in Western Europe, including medicine. He established the first hospital-based medical school in St. Petersburg and then in other centers, mainly to train military doctors. He established the Anatomical Museum of the Imperial Academy of Sciences in St. Petersburg in 1717, and initiated a census of males for military service in 1722. In 1724, V. N. Tateshev carried out a survey by questionnaire of all regions of the Russian empire regarding epidemic disease and methods of treatment.

ENLIGHTENMENT, SCIENCE, AND REVOLUTION (1750–1830)

The Enlightenment, a dynamic period of social, economic, and political thought, provided great impetus for emancipation and rapid advancement of science and agriculture, technology, and industrial power. Changes in many spheres of life were exemplified by the American and French revolutions, along with the economic theory of Adam Smith (author of *The Wealth of Nations*), which developed political and economic rights of the individual. Improvements in agriculture created greater productivity and better nutrition. These were associated with higher birth rates and falling death rates, leading to rapid population growth.

The agricultural revolution during the sixteenth and seventeenth centuries, based on mechanization and in larger land units of production with less manpower, led to rural depopulation, provided excess workers to staff the factories, mines, ships, homes, and shops of the industrial revolution, expanding commerce, and a growing middle class. Exploration and colonization provided expansion of markets that fueled the industrial revolution, growth of science, technology, and wealth.

An agricultural revolution improved methods of production of grain, milk, and meat through better land use, animal husbandry, and farm machinery resulting in greater agricultural productivity and food supply. Later, introduction of new crops from the Americas, including the potato, the tomato, peppers, and maize, contributed to a general improvement in nutrition. This was supplemented by increasing availability of cod from the Grand Banks of the Atlantic, adding protein to the common diet.

Industrialized urban centers grew rapidly. Crowded cities were ill-equipped to house and provide services for the growing working class. Urban areas suffered from crowding, poor housing, sanitation, and nutrition; harsh working conditions which produced appalling health conditions. During this period, documentation and statistical analysis developed in various forms, becoming the basis for social sciences including demography and epidemiology. Intellectual movements of the eighteenth century defined the rights of man and gave rise to revolutionary movements to promote liberty and release from tyrannical rule, as in the American and French revolutions of 1775 and 1789. Following the final defeat of Napoleon at Waterloo in 1815, conservative governments were faced with strong middle-class movements for reform of social conditions, with important implications for health.

Eighteenth-Century Reforms

The period of enlightenment and reason was led by philosophers Locke, Diderot, Voltaire, Rousseau, and others. These men produced a new approach to science and knowledge derived from observations and systematic testing of ideas as opposed to instinctive or innate knowledge as the basis for human progress. The idea of the rights of man contributed to the American and French revolutions, but also to a widening belief that society was obliged to serve all rather than just the privileged. This had a profound impact on approaches to health and societal issues.

The late eighteenth century was a period of growth and development of clinical medicine, surgery, and therapeutics, as well as of the sciences of chemistry, physics, physiology, and anatomy. From the 1750s onward, voluntary hospitals were established in major urban centers in Britain, America, and Eurasia. Medical–social reform involving hospitals, prisons, and lazarettos (leprosy hospitals) in Britain, led by John Howard (who published *On the State of Prisons* in 1777), produced substantive improvements in these institutions. During the French Revolution, Philippe Pinel removed the chains from patients at the Bicetre Mental Hospital near Paris and fostered reform of insane asylums. Reforms were further carried out in Britain by the Society of Friends (the Quakers), who built the York Retreat, providing humane care as an alternative to the inhuman conditions of the York Asylum.

Although Ramazzini's monumental work on occupational diseases was published in 1700, little progress was made in applying epidemiologic principles to this field. In the latter part of the century though, interest in the health of sailors and soldiers led to important developments in military and naval medicine. Studies of prevalent diseases were carried out by pioneering physicians among workers in various trades, such as metalworkers, bakers, shoemakers, and hat makers, and identified causative agents and thus methods of prevention. Observational studies of Percival Potts on scrotal cancer in chimney sweeps (1775), and Baker on the Devonshire colic (lead poisoning) in 1767, helped to lay the basis for development of investigative epidemiology.

Pioneers and supporting movements successfully agitated for reform in Britain through the parliamentary system. The anti-gin movement, aided by the popular newspapers (the "penny press") and the brilliant engravings of Hogarth, helped produce legal, social, and police reforms in English townships. Conditions for sailors in the British navy were improved following the explorations of Captain James Cook during the period 1766–1779, and the Spithead mutiny of 1797 and adoption of health recommendations of Captain James Lind. The United States developed the Marine Hospitals Service for treatment and quarantine of sailors in 1798, which later became the U.S. Public Health Service. The antislavery movement led by protestant Christian churches goaded the British government to ban slavery in 1797 and the slave trade in 1807, using the Royal Navy to sweep the slave trade from the seas during the early part of the nineteenth century.

Applied Epidemiology

Scurvy (the Black Death of the Sea) was a major health problem among sailors during long voyages. In 1498, Vasco da Gama lost 55 crewmen to scurvy during his voyages, and in 1535, Jacques Cartier's crew suffered severely from scurvy on his voyage of discovery to Canada. During the sixteenth century, Dutch sailors knew of the value of fresh vegetables and citrus fruit in preventing scurvy.

Purchas (1601) and John Woodall (a British naval doctor) (1617) recommended use of lemons and oranges in treatment of scurvy, but this was not widely practiced. During the seventeenth to eighteenth centuries, Russian military

Box 1.2 James Lind and Scurvy, 1747

Captain James Lind, a physician serving Britain's Royal Navy, developed a hypothesis regarding the cause of scurvy based on clinical observations. In May 1747, on HMS *Salisbury*, Lind conducted the first controlled clinical epidemiologic trial by treating 12 sailors sick with scurvy with six different dietary regimens. The two sailors who were fed oranges and lemons became well and fit for duty within 6 days, while the others remained sick. He concluded that citrus fruits would treat and prevent scurvy. In 1757, he published his *Treatise on the Scurvy: An Inquiry on the Nature, Causes and Cure of that Disease.*

This discovery was adopted by progressive sea captains and aided Captain Cook in his voyages of discovery in the South Pacific in 1768–1771. By 1795, the Royal Navy adopted routine issuance of lime juice to sailors to prevent scurvy. This extended the time naval ships could remain at sea, which was crucial in their blockade of Napoleonic Europe.

Lind also instigated reforms in living conditions for sailors, thus contributing to improvement in their health and fitness and the functioning of the fleet.

practice included antiscorbutic preparations, and use of sauerkraut for this purpose became common in European armies. Scurvy was a major cause of sickness and death among sailors when supplies of fruit and vegetables ran out; it caused disease and death which seriously limited long voyages and contributed to frequent mutinies at sea.

In 1740–1744, a British naval squadron of seven ships and nearly 2000 men led by Commodore George Anson left Plymouth, circumnavigating the globe, returned to England with one ship and 145 men after losing most of the crews to scurvy. In 1747, James Lind carried out a pioneering epidemiologic investigation on scurvy among sailors on long voyages, leading some 50 years later to adoption of lemon or lime juice as a routine nutrition supplement for British sailors. Vitamins were not understood or isolated until almost 150 years later, but Lind's scientific technique of careful observation, hypothesis formulation and testing, followed by documentation established clinical epidemiologic investigation of nutrition in public health (see Box 1.2).

Jenner and Vaccination

Smallpox, a devastating and disfiguring epidemic disease, ravaged all parts of the world and was known since the third century BCE. Described first by Rhazes in the tenth century, the disease was confused with measles and was widespread in Asia, the Middle East, and Europe during the Middle Ages. It was a designated cause of death in the Bills of Mortality in 1629 in London. Epidemics of smallpox occurred throughout the seventeenth to eighteenth and into the nineteenth centuries primarily as a disease of childhood, with mortality rates of 25 to 40 percent or more and disfiguring sequelae.

Smallpox was a key factor in the near elimination of the Aztec and other societies in Central and South America following the Spanish invasion. Traditions of prevention of this disease by inoculation or transmission of the disease to healthy persons to prevent them from a more virulent form during epidemics were reported in ancient China. This practice called variolation was first brought to England in 1721 by Lady Mary Montagu, wife of the British ambassador to Constantinople, where it was common practice. It was widely adopted in England in the mid-eighteenth century, when the disease affected millions of people in Europe. Catherine the Great in Russia had her son inoculated by variolation by a leading English practitioner.

Edward Jenner was the first to use vaccination with cowpox to prevent smallpox in 1796 (Box 1.3), initiating one of the most dramatically successful endeavors of public health, culminating in the eventual eradication of this dreaded killing and disfiguring disease. In 1800, vaccination was adopted by the British armed forces, and the practice spread to Europe, the Americas, and the British Empire. Denmark made vaccination mandatory in the early nineteenth century and soon eradicated smallpox locally. Despite some professional opposition, the practice spread rapidly from the upper classes and voluntary groups to the common people because of the fear of smallpox. Vaccination later became compulsory in many countries, leading to the ultimate public health achievement: global eradication of smallpox in the late twentieth century.

FOUNDATIONS OF HEALTH STATISTICS AND EPIDEMIOLOGY

Registration of births and deaths forms the basis of demography. Epidemiology as a discipline borrows from demography, sociology, and statistics. The basis of scientific reasoning in these fields emerged in the early seventeenth century with inductive reasoning enunciated by Francis Bacon and applied by Robert Boyle in chemistry, Isaac Newton in physics, William Petty in economics, and John Graunt in demography. Bacon's writing inspired a whole generation of scientists in different fields and led to the founding of the Royal Society.

In 1722, Peter the Great began Russia's system of registration of births of male infants for military purposes.

Box 1.3 Jenner and Smallpox

In 1796, Edward Jenner (1749–1823), a country physician in Gloustershire, England, investigated local folklore that milkmaids were immune to smallpox because of their exposure to cowpox. He took matter from a cowpox pustule on a milkmaid, Sarah Nelmes, and applied it with scratches to the skin of a youngster named James Phipps, who was then inoculated with smallpox. He did not develop the disease. Jenner's 1798 publication, A*n Enquiry into the Causes and Effects of the Variolae Vaccina*, described his wide-scale vaccination and its successful protection against smallpox, and prophesied that "the annihilation of the smallpox, the most dreadful scourge of the human species, must be the result of this practice."

He developed vaccination as a method to replace variolation, which was exposure of persons to the pustular matter of cases of smallpox, originally documented in ancient China in 320 CE. Variolation was practiced widely in the eighteenth century and constituted a very lucrative medical business. Opposition to vaccination was intense, and Jenner's contribution was ignored by the scientific and medical establishment of the day, but rewarded by Parliament. Vaccination was adopted as a universal practice by the British military in 1800 and by Denmark in 1803. Vaccination became an increasingly wide practice during the nineteenth century. In 1977, the last case of smallpox was identified and smallpox eradication was declared by the World Health Organization in 1980.

Remaining stocks of the virus in the United States and Russia were to be destroyed in 1999, but this was delayed and following the 9/11 attack on the Twin Towers in New York City, the threat of bioterrorism was taken seriously including the possibility of use of smallpox. As a result, vaccination was reinstated for "first responders" including fire, police, and hospital staff in the United States and other countries.

Source: WHO. Smallpox, http://www.bt.cdc.gov/agent/smallpox/ [accessed April 27, 2008]

In 1755, M. V. Lomonosov led initiatives in establishing the study of demography in Russia. He carried out surveys and studies of birth statistics, infant mortality, and quality of medical care, alcoholism, and worker's health. He brought the results of these studies to the attention of the government, which led to improved training of doctors and midwives, and epidemic control measures. Lomonosov also helped initiate the medical faculty of Moscow University (1765).

Daniel Bernoulli, a member of a European family of mathematicians, constructed life tables based on available data showing that variolation against smallpox conferred lifelong immunity and vaccination at birth increased life expectancy. Following the French Revolution, health statistics flourished in the mid-nineteenth century in the work of Pierre Louis, who is considered the founder of modern epidemiology. Louis conducted several important observational studies, including one showing that bloodletting, then a common form of therapy, was not effective, leading to a decline in this harmful practice. His students included Marc D'Epigne in France, William Farr in Britain, and others in the United States who became the pioneers in spreading "la methode numerique" in medicine.

Health statistics for social and public health reform took an important place in the work of Edwin Chadwick, Lemuel Shattuck, and Florence Nightingale. Recognizing the critical importance of accurate statistical information in health planning and disease prevention, Edwin Chadwick's work led to legislation establishing the Registrar-General's Office of Britain in 1836. William Farr became its director-general and placed the focus of this office on public health. Farr's analysis of mortality in Liverpool, for example, showed that barely half of its native-born lived to their sixth birthday, whereas in England overall the median age at death was 45 years. As a result, Parliament passed the Liverpool Sanitary Act of 1846, creating a legislated sanitary code, a Medical Officer of Health position, and a local health authority.

The London Epidemiological Society, founded in 1850, became an active investigative and lobbying group for public health action. Its work on smallpox led to passage of the Vaccination Act of 1853, establishing compulsory vaccination in the United Kingdom. William Budd, a student of Louis and founding member of the London Epidemiological Society, investigated outbreaks of typhoid fever in his home village in 1839, establishing it as a contagious self-propagating disease spread by microorganisms, discrediting the miasma theory.

In 1842 in Boston, Massachusetts, Lemuel Shattuck initiated a statewide registration of vital statistics, which became a model elsewhere in the United States. His report was a landmark in the evolution of public health administration and planning. This provided a detailed account of data collection by age, sex, race, occupation, and uniform nomenclature for causes of diseases and death. He emphasized the importance of a routine system for exchanging data and information.

In the later part of the nineteenth century, Florence Nightingale highlighted the value of a hospital discharge information system. She promoted collection and use of statistics that could be derived from the records of patients treated in hospitals. Her work led to improved management and design of hospitals, military medicine, and nursing as a profession.

SOCIAL REFORM AND THE SANITARY MOVEMENT (1830–1875)

Following the English civil war in 1646, veterans of the Parliamentary Army called on the government to provide free schools and free medical care throughout the country as part of democratic reform. However, they failed to sustain interest or gain support for their revolutionary ideas amidst postwar religious conflicts and restoration of the monarchy.

In Russia, the role of the state in health was promoted following initiatives of Peter the Great to introduce western medicine to the country. During the rule of Catherine the Great, under the supervision of Count Orlov, an epidemic of plague in Moscow (1771–1772) was suppressed by incentive payments to bring the sick for care. In 1784, a Russian physician, I. L. Danilevsky, defended a doctoral dissertation on "Government power — the best doctor." In the eighteenth and nineteenth centuries, reform movements promoted health initiatives by government. While these movements were suppressed (the Decembrists, 1825–1830) and liberal reform steps reversed, their ideas influenced later reforms in Russia.

Following the revolution in France, the Constituent Assembly established a Health Commission. A national assistance program for indigents was established. Steps were taken to strengthen the *Bureaux de Sante* (Offices of Health) of municipalities which had previously dealt primarily with epidemics. In 1802, the Paris Bureau addressed a wide range of public health concerns, including sanitation, food control, health statistics, occupational health, first aid, and medical care issues. The other major cities of France followed with similar programs over the next 20 years, and in 1848 a central national health authority was established. Child welfare services were also developed in France in the middle part of the nineteenth century. The reporting of vital statistics became reliable in the German states and even more so in France, fostering the development of epidemiologic analysis of causes of death.

The governmental approach to public health was articulated by Johann Peter Franck for the Germanic states in his monumental series of books, *A Complete System of Medical Police* (1779–1817). This text explained the government's role in states with strong central governments and how to achieve health reform through administrative action. State regulations were to govern public health and personal health practices including marriage, procreation, and pregnancy. He promoted dental care, rest following delivery and maternity benefits, school health, food hygiene, housing standards, sanitation, sewage disposal, and clean water supplies. In this system, municipal authorities were responsible for keeping cities and towns clean and for monitoring vital statistics, military medicine, venereal diseases, hospitals, and communicable disease.

This system emphasized a strong, even authoritarian role of the state in promoting public health including provision of prepaid medical care. It was a comprehensive and coherent approach to public health, emphasizing the key roles of municipal and higher levels of government. This work was influential in Russia where Franck spent the years 1805–1807 as director of the St. Petersburg Medical Academy. Because of its primary reliance on authoritarian governmental roles, however, this approach was resisted in most western countries, especially following the collapse of absolutist government ideas following the Napoleonic period.

Municipal (voluntary) boards of health were established in some British and American cities in the late eighteenth and early nineteenth centuries. A Central Board of Health was established in Britain in 1805, primarily to govern quarantine regulations to prevent entry of yellow fever and cholera into the country. Town life improved as sanitation, paving, lighting, sewers, iron water pipes, and water filtration were introduced, although organization for development of such services was inadequate. Multiple agencies and private water companies provided unsupervised and overlapping services. London City Corporation had nearly 100 paving, lighting, and cleansing boards, 172 welfare boards, and numerous other health-related authorities in 1830. These were later consolidated into the London Board of Works in 1855.

In Great Britain, early nineteenth-century reforms were stimulated by the Philosophic Radicals led by Jeremy Bentham, who advocated dealing with public problems in a rational and scientific way, initiating a reform movement utilizing parliamentary, legal, and educational means. Economic and social philosophers in Britain, including Adam Smith and Jeremy Bentham, argued for liberalism, rationalism, free trade, political rights, and social reform, all contributing to "the greatest good for the greatest number." Labor law reforms (the Mines and the Factory acts) banning children and women from underground work in the mines and regulating reduction in the workday to 10 hours were adopted by the British Parliament in the 1830s to 1840s. The spread of railroads and steamships, the penny post (1840), and telegraphs (1846), combined with growing literacy and compulsory primary education introduced in Britain in 1876, dramatically altered local and world communication.

The British Poor Law Amendment Act of 1834 replaced the old Elizabethan Poor Laws, shifting responsibility for welfare of the poor from the local parish to the central government's Poor Law Commission. The parishes were unable to cope with the needs of the rural poor whose condition was deteriorating with loss of land rights due to agricultural innovations and enclosures. The old system was breaking down, and the new industrialization needed workers, miners, sailors, and soldiers. The new conditions forced the poor to move from rural areas to

the growing industrial towns. The urban poor suffered or were forced into workhouses while resistance to reform led to more radicalization, unsuccessful revolution, followed by deep political conservatism.

Deteriorating housing, sanitation, and work conditions in Britain in the 1830s resulted in rising mortality rates recorded in the Bills of Mortality. Industrial cities like Manchester (1795) had established voluntary boards of health, but they lacked the authority to alter fundamental conditions to control epidemics and urban decay. The boards of health were unable to deal with sewage, garbage, animal control, crowded slum housing, privies, adulterated foods and medicines, industrial polluters, or other social or environmental risk sources. Legislation in the 1830s in Britain and Canada improved the ability of municipalities and boards of health to cope with oversight of community water supplies and sanitation.

Under pressure from reformists and the Health of Towns Association, the British government commissioned Edwin Chadwick to undertake a study which led to the *Report on the Sanitary Conditions of the Labouring Population of Great Britain* (1842), which led to a further series of reforms through the Poor Law Commission. The British Parliament passed the Health of Towns Act and the Public Health Act of 1848. This established the General Board of Health, mainly to ensure safety of community water supplies and drainage, establishing municipal boards of health in the major cities and rural local authorities, along with housing legislation, and other reforms. Despite setbacks due to reaction to these developments, the basis was laid for the "Sanitary Revolution," dealing with urban sanitation and health conditions, as well as cholera, typhoid, and tuberculosis control.

In 1850, the Massachusetts Sanitary Commission, chaired by Lemuel Shattuck, was established to look into similar conditions in that state. Boards of health established earlier in the century became efficiently organized and effective in sanitary reform in the United States. The report of that committee has become a classic public health document. Reissued in the 1970s, it remains a useful model for a comprehensive approach to public health.

The Chadwick (1842) and Shattuck (1850) reports developed the concept of municipal boards of health based on public health law with a public mandate to supervise and regulate community sanitation. This included urban planning, zoning, restriction of animals and industry in residential areas, regulation of working conditions, and other aspects of community infrastructure, setting the basis of public health infrastructure in the English-speaking world and beyond for the next century.

The interaction between sanitation and social hygiene was a theme promoted by Rudolph Virchow, the founder of cellular pathology and a social–medical philosopher. He was a leading German physician in the mid-nineteenth century, despite being an anticontagionist (i.e., a "miasmic"). He promoted the ideas of observation, hypothesis, and experimentation, helping to establish the scientific method and dispel philosophic approaches to medical issues. He was a social activist and linked health of the people to social and economic conditions, emphasizing the need for political solutions. Virchow played an important part in the 1848 revolutions in Central and Western Europe, the same year as the publication of the *Communist Manifesto* by Karl Marx. These all contributed to growing pressure on governments by workers' groups to promote better living, working, and health conditions in the 1870s.

In 1869, the Massachusetts State Board of Health was established and in the same year a Royal Sanitary Commission was appointed in the United Kingdom. The American Public Health Association (APHA), established in 1872, served as a professional educational and lobbying group to promote the interests of public health in the United States, often successfully prodding federal, state, and local governments to act in the public interests in this field. The APHA definition of appropriate services at each level of government continues to set standards and guidelines for local health authorities. The organization of local, state, and national public health activities over the twentieth century in the United States owes much to the professional leadership and lobbying skills of the APHA.

Max von Pettenkoffer in 1873 studied the high mortality rates of Munich, comparing them to rapidly declining rates in London. His public lectures on the value of health to a city led to sanitary reforms, as were being achieved in Berlin at the same time under Virchow's leadership. Pettenkoffer introduced laboratory analysis to public health practice and established the first academic chair in hygiene and public health, emphasizing the scientific basis for public health. He is considered to be the first professor of experimental hygiene. Pettenkoffer promoted the concept of the value of a healthy city, stressing that health is the result of a number of factors and public health is a community concern, and that measures taken to help those in need benefit the entire community.

In 1861, Russia freed the serfs and returned independence to universities. Departments of hygiene were established in the university medical schools in the 1860s and 1870s to train future hygienists, and to carry out studies of sanitary and health conditions in manufacturing industries. F. F. Erisman, a pioneer in sanitary research in Russia, promoted the connection between experimental science, social hygiene, and medicine, and he established a school of hygiene in 1890, later closed by the czarist government. In 1864, the government initiated the Zemstvos system of providing medical care in rural areas as a governmental program. These health

reforms were implemented in 34 of 78 regions of Russia, before the Revolution. Prior to these reforms, medical services in rural areas were practically nonexistent. Epidemics and the high mortality of the working population induced the nobility and new manufacturers in rural towns to promote Zemstvos' public medical services. In rural areas previously served by doctors based in the towns traveling to the villages, local hospitals and delivery homes were established. The Russian medical profession largely supported free public medical care as a fundamental right.

In 1881, Otto von Bismarck, Chancellor of Germany, introduced legislation providing mandatory insurance for injury and illness, and survivor benefits for workers in industrial plants, and then in 1883, introduced social insurance for health care of workers and their families, based on mandatory payments from workers' salaries and employer contributions. In the United Kingdom in 1911, Prime Minister Lloyd George established compulsory insurance for workers and their families for medical care based on capitation payment for general practitioner services. This was followed by similar programs in Russia in 1912 and in virtually all central and western European countries by the 1930s. In 1918, Vladimir Lenin established the state-operated health program, named for its founder Nikolai Semashko, bringing health care to the wide reaches of the Soviet Union. These programs led to the wide recognition of the principle of social solidarity with governmental responsibility for health of the population in virtually all developed countries by the 1960s (see Chapter 13). In the United States, pensions were established for Civil War veterans, widows and orphans, and were made a national Social Security system only in 1935. Health care insurance was developed through trade unions, and only extended to governmental medical care insurance for the elderly and the poor in 1965.

The harsh conditions in the urban industrial and mining centers of Europe during the industrial revolution led to efforts in social reform preceding and contributing to sanitary reform even before the germ theory of disease causation was proven and the science of microbiology established. Pioneering breakthroughs, based on trial and error, challenged the established dogmas of the time, produced the sanitary revolution, still one of the important foundations of public health.

Snow on Cholera

The great cholera pandemics originated in India between 1825 and 1854 and spread via increasingly rapid transportation to Europe and North America. Moscow lost some 33,000 people in the cholera epidemic of 1829, which recurred in 1830–1831. In Paris, the 1832 cholera epidemic killed over 18,000 people (just over 2 percent of the population) in 6 months.

Between 1848 and 1854, a series of outbreaks of cholera occurred in London with large-scale loss of life. The highest rates were in areas of the city where two water companies supplied homes with overlapping water mains. One of these (the Lambeth Company) then moved its water intake to a less polluted part of the Thames River, while the Southwark and Vauxhall company left its intake in a part of the river heavily polluted with sewage. John Snow, a founding member of the London Epidemiological Society and anesthetist to Queen Victoria, investigated an outbreak of cholera in Soho from August to September, 1854, in the area adjacent to Broad Street. He traced some 500 cholera deaths occurring in a 10-day period. Cases either lived close to or used the Broad Street pump for drinking water. He determined that brewery workers and poorhouse residents in the area, using uncontaminated wells, escaped the epidemic. Snow concluded that the Broad Street pump was probably contaminated. He persuaded the authorities to remove the handle from the pump, and the already subsiding epidemic disappeared within a few days.

During September to October, 1854, Snow investigated another outbreak, again suspecting water transmission. He identified cases of mortality from cholera by their place of residence and which water company supplied the home (Table 1.1). Snow calculated the cholera rates in a 4-week period in homes supplied by each of the two companies. Homes supplied by the Southwark and Vauxhall Water Company were affected by high cholera death rates while adjacent homes supplied by the Lambeth Company had rates lower than the rest of London. This provided overwhelming epidemiologic support for Snow's hypothesis that the cholera epidemic source was the contaminated water from the Thames River, distributed to homes in a large area of south London.

This investigation, with a study and control group occurring in an actual disease outbreak, strengthened the

TABLE 1.1 Deaths from Cholera Epidemic in Districts of London Supplied by Two Water Companies, 7 Weeks, 1854[a]

Water supply company	Number of houses	Deaths from cholera	Cholera deaths 10,000 houses
Southwark and Vauxhall	40,046	1,263	315
Lambeth	26,107	98	37
Rest of London	256,423	1,422	59

[a]Source: Snow J. On the mode of transmission of cholera. In: *Snow on Cholera*: A *Reprint of Two Papers*. New York: The Commonwealth Fund, 1936.

germ theory supporters who were still opposed by powerful forces. It also led to legislation mandating filtration of water companies' supplies in 1857. *Vibrio cholerae* was not isolated until 1883 during an investigation of waterborne cholera outbreaks in Egypt by Robert Koch. Snow's work on cholera has become one of the classic epidemiologic investigations, studied to this day for its scientific imagination and thoroughness, this despite preceding the discovery of the causative organism nearly 30 years later.

Snow's work on cholera stimulated more research into causes of enteric diseases. William Budd, physician at the Bristol Royal Infirmary, was a pioneering exponent of the germ theory of disease. He carried out a number of epidemiologic investigations of typhoid fever in the 1850s, finding waterborne episodes of the disease. He investigated an outbreak in 1853 in Cowbridge, a small Welsh village, where a ball attracted 140 participants from surrounding Counties. Almost immediately afterward, many of those attending the ball became sick with typhoid fever. He found that a person with typhoid had been at the location some days before and that his excreta had been disposed of near a well from which water was drawn for the ball. Budd then concluded that water was the vehicle of transmission of the disease. He investigated other outbreaks and summarized his reports in *Typhoid Fever: Its Nature, Mode of Transmission and Prevention,* published in 1873, which is a classic work on waterborne transmission of enteric disease. These investigations contributed to the movement to disinfect public water systems on a preventive basis.

The brilliant epidemiologic studies of Snow and Budd set a new direction in epidemiology and public health practice, not only with waterborne disease. They established a standard for investigation of the distribution of disease in populations with the object of finding a way to interrupt the transmission of disease. Improved sanitation and water safety developed in urban and rural population centers contributed greatly to improved survival and decrease in cholera and typhoid epidemics. However, globally, waterborne disease remains a major cause of morbidity and mortality especially among children to the present day.

Germ Versus Miasma Theories

Until the early and middle parts of the nineteenth century, the causation of disease was hotly debated. The miasma theory, holding that disease was the result of environmental emanations or miasmas, went back to Greek and Roman medicine, and Hippocrates (Air, Water, and Places). Miasmists believed that disease was caused by infectious mists or noxious vapors emanating from filth in the towns and that the method of prevention of infectious diseases was to clean the streets of garbage, sewage, animal carcasses, and wastes that were features of urban living. This provided the basis for the Sanitary Movement, with great benefit to improving health conditions. The miasma theory had strong proponents well into the later part of the nineteenth century.

The contagion or germ theory gained ground, despite the lack of scientific proof, on the basis of biblical and Middle Ages experience with isolation of lepers and quarantine of other infectious conditions. In 1546, Fracastorus published *De Contagione,* a treatise on microbiological organisms as the case of specific diseases. The germ theory was strengthened by the work of Antony van Leeuwenhoek, who invented the microscope in 1676. The invention of this apparatus is considered to be a watershed in the history of science. His research showing small microorganisms led to his recognition as a Fellow of the Royal Society of England in 1680. The germ theorists believed that microbes, such as those described by van Leeuwenhoek, were the cause of diseases which could be transmitted from person to person or by contact with sewage or contaminated water.

Major contributions to resolving this issue came from the epidemiologic studies of Snow and Budd in the 1850s, proving waterborne transmission of cholera and typhoid. The classic study of a measles epidemic in the remote Faroe Islands by Peter Panum in 1846 clearly showed person-to-person transmission of this disease, its incubation period, and the lifelong natural immunity exposure gives (Box 1.4). The dispute continued, however, with miasmists or sanitationists arguing with equal vehemence.

While the science of the issue was debated until the end of the nineteenth century, the practical application of sanitary reform was promoted by both theories. Increasing attention to sewage, water safety, and removal of waste products by organized municipal activities was adopted in European and North American cities. The sanitary revolution proceeded while the debates raged and solid scientific proof of the germ theory accumulated, primarily in the 1880s. Fear of cholera stimulated New York City to establish a Board of Health in 1866. In the city of Hamburg, Germany, a Board of Health was established in 1892 only after a cholera epidemic attacked the city, while neighboring Altona remained cholera-free because it had established a water filtration plant.

The specific causation of disease (the germ theory) has been a vital part of the development of public health. The bacteriologic revolution (see later section entitled "Bacteriologic Revolution"), led by the work of Louis Pasteur and Robert Koch, provided enormous benefit to medicine and public health. But those who argued that disease is environmental in origin (the miasma theory) also contributed to public health because of their recognition of the importance of social or other environmental factors, such as poor sanitation and housing conditions or nutritional status, all of which increase susceptibility to specific agents of disease, or the severity of disease.

Box 1.4 Panum on Measles in the Faroe Islands, 1846

Peter Ludwig Panum, a 26-year-old newly graduated medical doctor from the University of Copenhagen, was sent to the Faroe Islands by the Danish government to investigate an outbreak of measles in 1846. There had been no measles since 1781 in the islands, located in the far reaches of the North Atlantic. During the 1846 epidemic, about 6000 of the 7782 islanders were stricken with measles and 102 of them died of the disease or its sequelae. Panum visited all isolated corners of the islands, tracing the chain of transmission of the disease from location to location, and the immunity of those exposed during the 1781 epidemic.

From his well-documented observations he concluded, contrary to prevailing opinion, that measles is a contagious disease spread from person to person, and that one attack gives lifelong immunity. His superb report clearly demonstrated the contagious nature of the disease, its incubation period, and that it is not a disease of "spontaneous generation," nor is it generally dispersed in the atmosphere and spread as a "miasma," proving that isolation of cases was an effective intervention.

Despite availability of an inexpensive, highly effective, and safe vaccine since the 1960s, and elimination of domestic circulation of the virus in many countries, measles remains a serious global health problem in 2008. An estimated 250 thousand children died of measles in 2006, and outbreaks of measles are occurring in countries that were thought to be measles free as a result of imported cases and local spread. Measles elimination is possible with the two dose policy with current vaccines if immunization is given high priority and with determined national and international priority and efforts.

Source: Panum, P. L. *Observations Made During the Epidemic of Measles on the Faroe Islands in the Year* 1846. From: Roueche, B. (ed.) op. cit.
WHO. Measles, http://www.who.int/mediacentre/factsheets/fs286/en/ [accessed April 27, 2008]

HOSPITAL REFORM

Hospitals developed by monasteries as charitable services were supplanted by voluntary or municipal hospitals mainly for the poor during and after the Renaissance. Reforms in hospital care evolved along with the sanitary revolution. In eighteenth-century Europe, hospitals operated by religious orders of nuns and by municipal or charitable organizations were dangerous cesspools of pestilence because of lack of knowledge about and practice of infection control, concentration of patients with highly communicable diseases, and transmission of disease by medical and other staff.

Reforms in hospitals in England were stimulated by the reports of John Howard in the late eighteenth century, becoming part of wider social reform in the early part of the nineteenth century. Professional reform in hospital organization and care started in the latter half of the nineteenth century under the influence of Florence Nightingale, Oliver Wendel Holmes, and Ignaz Semmelweiss. Clinical–epidemiologic studies of "antiseptic principles" provided a new, scientific approach to improvement in health care.

In the 1840s, puerperal fever was a major cause of death in childbirth, and was the subject of investigation by Holmes in the United States, who argued that this was due to a contagion. In 1846, Semmelweiss, a Hungarian obstetrician at the Vienna Lying-In Hospital, suspected that deaths from puerperal fever were the result of contamination on the hands of physicians transmitted from autopsy material to living patients. He showed that death rates among women attended by medical personnel were two to five times the rates among those attended by midwives. By requiring doctors and medical students to soak their hands in chlorinated lime after autopsies, he reduced the mortality rates among the medically attended women to the rate of the midwife-attended group.

Semmelweiss's work, although carefully documented, was slow to be accepted by the medical community, taking some 40 years for general adoption. His pioneering investigation of childbed fever (streptococcal infection in childbirth) in Vienna contributed to improvement in obstetrics and a reduction in maternal mortality. In the 1850s, prevention of blindness in newborns by prophylactic use of silver nitrate eyedrops, developed by Karl Crede in Leipzig, spread rapidly through the medical world (Box 1.5). This practice continues to be a standard in prevention of ophthalmia neonatorum.

Florence Nightingale's momentous work in nursing and hospital administration in the Crimean War (1854–1856) established the professions of nursing and modern hospital administration. In the 1860s, she emphasized the importance of poor law and workhouse reform and training special district nurses for care of the sick poor at home. Nightingale's subsequent long and successful campaigns to raise standards of military medicine, hospital planning, supply services and management, hospital statistics, and community health nursing were outstanding contributions to the development of modern, organized health care and antisepsis.

Despite all the cumulative progress over the past 150 years, such as the advent of sterile techniques and antibiotics, hospital-acquired infection remains a serious public health problem to the present time with multidrug-resistant organisms and a persistent failure of regular use of simple hand washing between patient care by doctors and nurses, and in antiseptic measures need for invasive procedures such as central venous and bladder catheters.

Box 1.5 Crede and Prevention of Gonococcal Ophthalmia Neonatorum

Gonorrhea was common in all levels of society in nineteenth-century Europe and ophthalmic infection of newborns was a widespread cause of infection, scarring, and blindness. Carl Franz Crede, professor of obstetrics at the University of Leipzig, attempted to treat neonatal gonococcal ophthalmic infection with many medications. Crede discovered the use of silver nitrate as a treatment and introduced its use as a preventive measure during the period 1854–1860 with astonishing success.

The prophylactic use of silver nitrate spread rapidly hospital by hospital, but it was decades before it was mandated widely because of widespread medical opposition to this innovation. It was only in 1879 that the gonococcus organism was discovered by Neisser. Estimates of children saved from blindness by this procedure in Europe during the nineteenth century are as high as one million.

Source: Schmidt A. 2007. Gonorrheal ophthalmia neonatorum. In *Pediatric Infectious Diseases Revisited*. Birkhäuser Basel. http://www.springerlink.com/content/xtu8475716207264/ [accessed April 27, 2008]

THE BACTERIOLOGIC REVOLUTION

In the third quarter of the nineteenth century, the sanitary movement rapidly spread through the cities of Europe with demonstrable success in reducing disease in areas served by sewage drains, improved water supplies, street paving, and waste removal. At the same time, innovations occurred in hospitals, stressing hygiene and professionalization of nursing and administration. These were accompanied by breakthroughs in establishing scientific and practical applications of bacteriology and immunology.

Pasteur, Cohn, Koch, and Lister

In the 1850s to 1870s, Louis Pasteur, a French professor of chemistry, brilliantly developed the basis for modern bacteriology as a cornerstone of public health. He established a scientific, experimental proof for the germ theory with his demonstration in 1854 of anaerobic microbial fermentation. Between 1856 and 1860 he showed how to prevent wine from spoilage due to contamination from foreign organisms by heating the wine to a certain temperature before bottling it to kill the undesired ferments. This led to the process of "pasteurization." Asked to investigate the threatened destruction of the French silk industry by epidemics destroying the silkworms, he discovered microorganisms (1865) causing the disease and devised new growing conditions which eliminated the problem, raising scientific and industrial interest in the germ theory. This was followed by similar work in the beer industry (1871).

Pasteur went on to develop the science of immunology by working with vaccines. He produced vaccines from attenuation or weakening an organism's strength by passing it successively through animals, recovering it and retransmitting it to other animals. In 1881, he inoculated hens with attenuated cultures of chicken cholera and then in an inspired experiment challenged them with virulent organisms and found them to be immune. In 1883, he produced a similar protective vaccine for swine erysipelas, and then in 1884–1885, a vaccine for rabies.

Rabies was widely feared as a disease transmitted to humans through bites of infected animals and was universally fatal. Pasteur reasoned that the disease affected the nervous system and was transmitted in saliva. He injected material from infected animals, attenuated to produce protective antibodies but not the disease. In 1885, a 14-year-old boy from Alsace was severely bitten by a rabid dog. Local physicians agreed that because death was certain, Pasteur, a chemist and not a physician, be allowed to treat the boy with a course of immunization. The boy, Joseph Meister, survived, and similar cases were brought to Pasteur and the person successfully immunized. Pasteur was criticized in medical circles, but both the general public and scientific circles soon recognized his enormous contribution to public health.

Ferdinand Julius Cohn (1828–1898), professor of Botany at Breslau University, developed and systematized the science of bacteriology using morphology, staining, and media characteristics of microorganisms, and trained a key generation of microbiological investigators. One student, Robert Koch (1843–1910), a German rural district medical officer, investigated anthrax using mice inoculated with blood from sick cattle, transmitting the disease for more than 20 generations. He developed basic bacteriologic techniques including methods of culturing and staining bacteria. He demonstrated the organism causing anthrax, recovered it from sick animals, and passed it through several generations of animals, proving the transmission of specific disease by specific microorganisms.

In 1882, Koch demonstrated and cultured the tubercle bacillus. He then headed the German Cholera Commission visiting Egypt and India in 1883, isolating and identifying *Vibrio cholerae* (Nobel Prize, 1905).

He demonstrated the efficacy of water filtration in preventing transmission of enteric disease including cholera. In 1883, Koch, adapting postulates on causation of disease from clinician–pathologist Jacob Henle (1809–1885), established criteria for attribution of causation of a disease to a particular parasite or agent (Box 1.6). These were fundamental to establishment of the science of bacteriology and the relationship of microorganisms to disease causation.

The Koch-Henle postulates in their pure form were too rigid, and would limit identification of causes of many diseases, but they were important in establishing germ theory and the scientific basis of bacteriology, dispelling the many other theories of disease still widespread in the late nineteenth century. These postulates served as guidelines for evidence of causation, but had limitations in that not all microbiologic agents can be grown in pure culture, some organisms undergo antigenic drift or change in antigenicity, and there is no animal host for some organisms. Koch's postulates were later adapted by Evans (1976) to include noninfectious disease-causing agents, such as cholesterol, following the changing emphasis in epidemiology of noninfectious diseases.

In the mid-1860s, Joseph Lister in Edinburgh, under the influence of Pasteur's work and with students of Semmelweiss, developed a theory of "antisepsis." His 1865 publication *On the Antiseptic Principle in the Practice of Surgery* described the use of carbolic acid to spray operating theaters and to cleanse surgical wounds, applying the germ theory with great benefit to surgical outcomes. Lister's work on chemical disinfection for surgery in 1865 was a pragmatic development and a major advance in surgical practice; an important contribution to establishing the germ theory in nineteenth-century medicine.

Box 1.6 The Koch-Henle Postulates on Microorganisms as the Cause of Disease

1. The organism (agent) must be shown to be present in every case of the disease by isolation in pure culture;
2. The agent should not be found in cases of any other disease;
3. Once isolated, the agent should be grown in a series of cultures, and then must be capable of reproducing the disease in experimental animals;
4. The agent must then be recovered from the disease produced in experimental animals.

Source: Last, J. M. 2001. A *Dictionary of Epidemiology*. 4th ed. New York: Oxford University Press.
Last, J. M. 2006. A *Dictionary of Public Health* and http://www.medterms.com/script/main/art.asp?articlekey=7105 [accessed December 24, 2007]

Vector-Borne Disease

Studies of disease transmission defined the importance of carriers (i.e., those who can transmit a disease without showing clinical symptoms) in transmission of diphtheria, typhoid, and meningitis. This promoted studies of diseases borne by intermediate hosts or vectors. Parasitic diseases of animals and man were investigated in many centers during the nineteenth century, including Guinea worm disease, tapeworms, filariasis, and veterinary parasitic diseases such as Texas cattle fever. David Bruce demonstrated transmission of nagana (animal African trypanosomiasis), a disease of cattle and horses in Zululand, South Africa, in 1894–1895, caused by a trypanosome parasite transmitted by the tsetse fly, leading to environmental methods of control of disease transmission. Alexandre Yersin and Shibasabro Kitasato discovered the plague bacillus in 1894, and in 1898 French epidemiologist P. L. Simmond demonstrated the plague was a disease of rats spread by fleas to humans.

Malarial parasites were identified by French army surgeon Alphonse Laveran (Nobel Prize, 1907) in Algeria in 1880. Mosquitoes were suspected as the method of transmission by many nineteenth-century investigators, and in 1897 Ronald Ross (Nobel Prize, 1902), a British army doctor in India, Patrick Manson in England, and Benvenuto Grassi in Rome demonstrated transmission of malaria by the *Anopheles* mosquito. Yellow fever, probably imported by the slave trade from Africa, was endemic in the southern United States but spread to northern cities in the late eighteenth century. An outbreak in Philadelphia in 1798 killed nearly 8 percent of the population. Outbreaks in New York killed 732 people in 1795, 2086 in 1798, and 606 in 1803. The Caribbean and Central America were endemic with both yellow fever and malaria.

The conquest of yellow fever also contributed to establishing the germ or contagion theory versus the miasma theory when the work of Cuban physician Carlos Finlay was confirmed by Walter Reed in 1901. His studies in Cuba proved the mosquito-borne nature of the disease as a transmissible disease via an intermediate host (vector) but not contagious between humans. William Gorgas applied this to vector control activities and protection of sick persons from contact with mosquitoes, resulting in an eradication of yellow fever in Havana within 8 months, and in the Panama Canal Zone within 16 months (Box 1.7). This work showed a potential for control of vector-borne disease that has had important success in control of many tropical diseases, including yellow fever and, currently, Guinea worm disease and onchocerciasis. Malaria, although it has come under control in many parts of the world, has resurged in many tropical countries since the 1960s.

Box 1.7 Havana and Panama: Control of Yellow Fever and Malaria, 1901–1906

The United States Army Commission on Yellow Fever led by Walter Reed, an Army doctor, worked with Cuban physicians Carlos Finlay and Jesse Lazear to experiment with yellow fever transmission in Cuba in 1901. Working with volunteers, he demonstrated transmission of the disease from person to person by the specific mosquito, *Stegomyia fasciata*. The Commission accepted that "the mosquito acts as the intermediate host for the parasite of Yellow Fever."

Another U.S. army doctor, William Gorgas, applied the new knowledge of transmission of yellow fever and the life cycle of the vector mosquito. He organized a campaign to control the transmission of yellow fever in Havana, isolating clinical cases from mosquitoes and eliminating the breeding places for the *Stegomyia* with Mosquito Brigades. Yellow fever was eradicated in Havana within 8 months. This showed the potential for control of other mosquito-borne diseases, principally malaria with its specific vector, *Anopheles*. Gorgas then successfully applied mosquito control to prevent both yellow fever and malaria between 1904 and 1906, permitting construction of the Panama Canal.

MICROBIOLOGY AND IMMUNOLOGY

Ilya Ilyich Mechnikov in Russia in 1883 described phagocytosis, a process in which white cells in the blood surround and destroy bacteria, and his elaboration of the processes of inflammation and humoral and cellular response led to a joint Nobel Prize in 1908 with Paul Ehrlich. Other investigators searched for the bactericidal or immunological properties of blood that enabled cell-free blood or serum to destroy bacteria. This work greatly strengthened the scientific bases for bacteriology and immunology.

Pasteur's co-workers, Emile Roux and Alexandre Yersin, isolated and grew the causative organism for diphtheria and suggested that the organism produced a poison or toxin which caused the lethal effects of the disease. In 1890, Karl Fraenkel in Berlin published his work showing that inoculating guinea pigs with attenuated diphtheria organism could produce immunity. At the same time, Emile Behring in Germany with Japanese co-worker Shibasaburo Kitasato produced evidence of immunity in rabbits and mice to tetanus bacilli. Behring also developed a protective immunization against diphtheria in humans with active immunization as well as an antitoxin for passive immunization of an already infected person (Nobel Prize, 1901). By 1894, diphtheria antitoxin was ready for general use. The isolation and identification of new disease-causing organisms proceeded rapidly in the last decades of the nineteenth century. The diphtheria organism was discovered in 1885 by Edwin Klebs and Friedrich Loeffler (students of Koch), and a vaccine for it was developed in 1912, leading to the control of this disease in many parts of the world. Between 1876 and 1898, many pathogenic organisms were identified, providing a basis for advances in vaccine development.

During the last quarter of the nineteenth century, it was clear that inoculation of attenuated microorganisms could produce protection through active immunization of a host by generating antibodies to that organism, which would protect the individual when exposed to the virulent (wild) organism. Passive immunization could be achieved in an already infected person by injecting the serum of animals infected with attenuated organisms. The serum from that animal helps to counter effects of the toxins produced by an invading organism. Pasteur's vaccines were followed by those of Waldemar Haffkine, a bacteriologist working in India; the first microbiologist to develop and use vaccines against cholera and bubonic plague, after testing on himself. Other pioneering achievements include those of Richard Pfeiffer and Carroll Wright for typhoid, Albert Calmette and Alphonse Guerin for tuberculosis, and Arnold Theiler and Theobald Smith for yellow fever.

The twentieth century has seen the flowering of immunology in the prevention of important diseases in animals and in man based on the pioneering work of Jenner, Pasteur, Koch, and those who followed. Many major childhood infectious diseases have come under control by immunization in one of the outstanding achievements of twentieth-century public health.

Poliomyelitis

Poliomyelitis was endemic in most parts of the world prior to World War II, causing widespread crippling of infants and children, hence its common name of "infantile paralysis." The most famous polio patient was Franklin Delano Roosevelt, crippled by polio in his early 30s, who went on to become president of the United States. During the 1940s and 1950s, poliomyelitis occurred in massive epidemics affecting thousands of North American children and young adults, with national hysteria of fear of this disease because of its crippling and killing power. In 1952, 52,000 cases of poliomyelitis were reported in the United States, bringing a national response and support for the "March of Dimes" Infantile Paralysis Association for research and field vaccine trials.

Based on the development of methods for isolating and growing the virus by John Enders and colleagues, Jonas Salk developed an inactivated vaccine in 1955 and Albert Sabin a live attenuated vaccine in 1961. Salk's field trial proved the safety and efficacy of his vaccine in preventing poliomyelitis. Sabin's vaccine proved to be cheaper and easier to use on a mass basis and is still the mainstay of

Box 1.8 Enders, Salk, Sabin, and Eradicating Poliomyelitis

In the early 1950s, John Enders and colleagues developed methods of growing polio virus in laboratory conditions, for which they were awarded a Nobel Prize. At the University of Pittsburgh, Jonas Salk (1914–1995) developed the first inactivated (killed) vaccine under sponsorship of a large voluntary organization which mobilized the resources to fight this dreaded disease. Salk conducted the largest field trial ever involving 1.8 million children in 1954. The vaccine was rapidly licensed and quickly developed and distributed in North America and Europe, interrupting the epidemic cycle and rapidly reducing polio incidence to low levels.

Albert Sabin (1906–1994) at the University of Cincinnati developed a live, attenuated vaccine given orally (OPV), which was approved for use in 1961. This vaccine has many advantages: it is given easily, spreads its benefits to nonimmunized persons, and is inexpensive. It became the vaccine of choice and was used widely reducing polio to a negligible disease in most developed countries within a few years. Sabin also pioneered application of OPV through national immunization days in South America which contributed to control of polio there, and more recently, in other countries such as China and India.

In 1987, the World Health Organization declared the target of eradication of poliomyelitis by the year 2000. With the help of international and national commitment, the Americas were declared polio-free in 1990. Polio at the end of 2007 continues in only several countries, and eradication of the natural transmission of the disease is anticipated now by 2010. Salk vaccine is being adopted by most western countries, but OPV continues to be used in most parts of the world.

polio eradication worldwide (Box 1.8). Conquest of this dreaded, disabling disease has provided one of the most dramatic achievements of public health in the twentieth and early twenty-first centuries with good prospects for elimination of poliomyelitis by 2010 (see Box 1.8).

Advances in Treatment of Infectious Diseases

Since World War II, advances in immunology as applied to public health led to the control and in some cases potential eradication of diphtheria, pertussis, tetanus, poliomyelitis, measles, mumps, rubella, and more recently hepatitis B and *Haemophilus influenzae* type b. The future in this field is promising and will play a central role in public health well into the twenty-first century.

Treatment of infectious diseases has also played a vital part in reducing the toll of disease and limiting its spread. In 1909, Paul Ehrlich, awarded the Nobel Prize in 1908 jointly with Methchnikov, seeking a "magic bullet," discovered an effective antimicrobial agent for syphilis (Salvarsan). Later more important antimicrobial antibiotics were discovered in the 1920s, followed by the sulfa drugs in the 1930s, and the antibiotics and penicillin and streptomycin in the 1940s by Alexander Fleming and Selman Waksman (Nobel Prizes, 1945 and 1952). These and later generations of antibiotics have proven powerful tools in the treatment of infectious diseases.

Antibiotics and vaccines, along with improved nutrition, general health, and social welfare, led to dramatic reductions in infectious disease morbidity and mortality. As a result, optimistic forecasts of the conquest of communicable disease led to widespread complacency in the medical and research communities by the late twentieth century. In the 1990s, organisms resistant to available antibiotics constituted a major problem for public health and health care systems. Resistant organisms are now evolving as quickly as newer generation antimicrobials can be developed, threatening a return of diseases once thought to be under control. The pandemic of AIDS and other emerging and re-emerging diseases like SARS will require new strategies in treatment and prevention including new vaccines, antibiotics, chemotherapeutic agents, and risk reduction through community education.

MATERNAL AND CHILD HEALTH

Preventive care for the special health needs of women and children developed as public concerns in the late nineteenth century. Public awareness of severe conditions of women's and children's labor grew to include the effects on health of poverty, poor living conditions and general hygiene, home deliveries, lack of prenatal care, and poor nutrition.

Preventive care as a service separate from curative medical services for women and children was initiated in the unsanitary urban slums of industrial cities in nineteenth-century France in the form of milk stations (*gouttes de lait*). One village in France instituted an incentive payment to mothers whose babies lived to 1 year; this resulted in a decline in infant mortality from 300 per 1000 to 200 per 1000 within a few years. The plan was later expanded to a complete child welfare effort, especially promoting breast-feeding and a clean supply of milk to children, which had dramatic effects in reducing infant deaths.

The concept of child health spread to other parts of Europe and the United States with the development of pediatrics as a specialty and an emphasis on appropriate child nutrition. Henry Koplik in 1889 and Nathan Strauss

in 1893 promoted centers to provide safe milk to pregnant women and children in the slums of New York City in order to combat summer diarrhea. The Henry Street Mission, serving poor immigrant areas, developed the model of visiting nurses and public milk stations. The concept of the "milk station," combined with home visits, was pioneered by Lillian Wald, who coined the term *district nurse* or *public health nurse*. This became the basis for public prenatal, postnatal, and well-child care as well as school health supervision. Visiting Nursing Associations (VNAs) gradually developed throughout the United States to provide such services. Physicians' services in the United States were mainly provided on a fee-for-service basis for those able to pay, with charitable services in large city hospitals. The concept of direct provision of care to those in need by local authorities and by voluntary charitable associations, with separation between preventive and curative services, is still a model of health care in many countries.

In Jerusalem, from 1902, Shaare Zedek Hospital kept cows to provide safe milk for infants and pregnant women. In 1911, two public health nurses came from New York to Jerusalem to establish milk stations (*Tipat Halav,* "drop of milk") for poor pregnant women and children. This model became the standard method of Maternal and Child Health (MCH) provision throughout Israel, operating parallel to the Sick Funds which provided medical care. The separation between preventive and curative services persists to the present, and is sustained by the Israeli national government's obligation to assure basic preventive care to all regardless of insurance or ability to pay.

In the Soviet Union, institution of the state health plan in 1918 by Nikolai Aleksandrovich Semashko gave emphasis to maternal and child health, along with epidemic and communicable disease control. All services were provided free as a state responsibility through an expanding network of polyclinics and other services, and prenatal and child care centers, including preventive checkups, home visits, and vaccinations. Infant mortality declined rapidly even in the Asian republics with previously poor health conditions.

During the 1990s, the United States was having difficulty immunizing children in high poverty areas of urban centers and adopted immunization as part of their Women, Infants, and Children (WIC) food support program for poor pregnant women and children, helping to achieve much higher coverage levels in years since.

The emphasis placed on maternal and child health continues to be a keystone of public health. Care of children and women in relation to fertility is the application of what later came to be called the "risk approach," where attention is focused on designing health programs for the most vulnerable groups in the population.

NUTRITION IN PUBLIC HEALTH

As infectious disease control and later maternal and child health became public health issues in the eighteenth to nineteenth centuries, nutrition gained recognition from the work of pioneers such as James Lind (see preceding section entitled "Applied Epidemiology"). In 1882, Kanehiro Takaki, surgeon-general of the Japanese navy, reduced incidence of beriberi among naval crews by adding meat and vegetables to their diet of rice. In 1900, Christiaan Eijkman, a Dutch medical officer in the East Indies, found that inmates of prison camps who ate polished rice developed beriberi, while those eating whole rice did not. He also produced beriberi experimentally in fowls on a diet of polished rice, thus establishing the etiology of the disease as a deficiency condition and fulfilling a nutritional epidemiologic hypothesis. Eijkman was awarded the Nobel Prize in physiology or medicine in 1929.

In the United States, the pioneering Pure Food and Drug Act was passed in 1906, stimulated by journalistic exposures of conditions in the food industry and Upton Sinclair's famous 1906 novel *The Jungle*. The legislation established federal authority in food and labeling standards, originally for interstate commerce, but later for the entire country. This provided for a federal regulatory agency and regulations for food standards. The Food and Drug Administration (FDA) has pioneered nutritional standards now used throughout the world.

In the early part of the twentieth century, the U.S. Department of Agriculture (USDA) supported "land grant colleges" and rural counties to establish an extension service to promote agricultural improvement and good nutrition in poor agricultural areas of the country. These services, along with local women's organizations, helped create a mass movement to improve good nutrition, canning surplus foods, house gardening, home poultry production, home nursing, furniture refinishing, and other skills that helped farm families survive the years of economic depression and drought, promoting better nutrition through education and community participation.

In 1911, the chemical nature of vitamin D was discovered, and a year later, Kasimir Funk coined the term vitamin ("vital amine"). In 1914, Joseph Goldberger of the U.S. Public Health Service established the dietary causes of pellagra and in 1928 he discovered the pellagra-preventing factor in yeast (Box 1.9). In 1916, U.S. investigators defined fat-soluble vitamin A and water-soluble vitamin B, which was later shown to be more than one factor. In 1922, Elmer McCollum identified vitamin D in cod liver oil, which became a staple in child care for many decades. In the period 1931–1937, fluoride in drinking water was found to prevent tooth decay, and in 1932 vitamin C was isolated from lemon juice.

Iodization of salt to prevent iodine deficiency disorders (IDD) has been one of the greatest successes and

Box 1.9 Goldberger on Pellagra

"Mal de la rosa," first described in Spain by Casal in 1735, was common in northern Italy, when, in 1771, Frappolli described "pelle agra" or farmers' skin, common among poor farmers whose diet was mainly corn flour. In 1818, Hameau described a widespread skin disease among poor farmers in southern France. Roussel investigated and concluded that pellagra was endemic and due to poverty rather than a diet heavy in corn. His recommended reforms were implemented by the Department of Agriculture and raised standards of living among the poor farmers, including growing wheat and potatoes instead of corn, and the disease disappeared by the beginning of the twentieth century. Similar measures in Italy reduced growth of corn, and here too the disease disappeared.

The disorder was thought to be due to a toxin in raw corn or produced by digestion in the intestine. Lambrozo, in Verona, Italy, reported many cases of pellagra among mental hospital patients, concluding that it was due to toxic material in corn. At the beginning of the twentieth century, the corn theory was less accepted and the common view was that pellagra was an infectious disease. British investigator L. V. Sambon, discoverer of the role of the tsetse fly in trypanosomiasis in 1910 took the view that the disease was mosquito-borne.

Pellagra was first reported in the United States in 1906 as an epidemic in a mental hospital in Alabama. In the first decades of the twentieth century, pellagra was considered the leading public health problem in the southern United States, where poverty was rampant. The medical community had no ideas as to the cause or prevention of this widespread disease, generally believed to be infectious in origin.

In 1913, Joseph Goldberger was appointed by the U.S. Public Health Service to investigate pellagra. He had previously worked on yellow fever, dengue, and typhus. He visited psychiatric hospitals and orphanages with endemic pellagra and was struck by the observation that the staff was not affected, suggesting that the disease was not infectious but may have been due to the diet. In one mental hospital, he eliminated pellagra by adding milk and eggs to the diet and concluded that the disease was due to a lack of vitamins and preventable by a change in diet alone. Goldberger, trained in infectious disease, was able to recognize non-transmission from patients to staff and went on to establish the nutritional basis of this disease and, along with Lind, established nutritional epidemiology in public health.

failures of twentieth-century public health. From studies in Zurich and in the United States, the efficacy of iodine supplements in preventing goiter was demonstrated. Morton's iodized salt became a national standard in the United States; an early and noble example of voluntary public health action by private industry. In Canada in 1979, iodized salt became mandatory along with other vitamin and mineral fortification of bread and milk (see Chapter 8).

Rickets, still common in industrialized countries prior to World War II and into the 1950s, virtually disappeared following fortification of milk with vitamin D. Prevention of IDD by salt iodization has become an important goal in international health, and progress is being made toward universal iodization of salt in many countries where goiter, cretinism, and iodine deficiency are still endemic.

The international movement to promote proper nutrition is vital to reduce the toll of the malnutrition–infection cycle in developing countries. No less important is prevention of noncommunicable diseases associated with over-nutrition, including cardiovascular diseases, diabetes, and some cancers in industrialized nations. Nutrition is a key issue in the New Public Health, with international movements to eradicate vitamin and mineral (micronutrient) deficiency conditions, all of which are important, widespread, and preventable.

MILITARY MEDICINE

Professional armies evolved with urban civilizations and developed in the ancient world from about 4000 BCE. Since organized conflict began, armies have had to deal with the health of soldiers as well as treatment of the wounded. Injunctions on military and civilian camp siting and sanitation were clearly spelled out in the Bible (Old Testament). Roman armies excelled at construction of camps with care and concern for hygienic conditions, food, and medical services for the soldiers. Throughout history, examples of defeat of armies by disease and lack of support services prove the need for serious attention to the health and care of the soldier. Studies of casualties of war in major conflicts contribute not only to military medicine but to knowledge of the care of civilian populations in natural or man-made disasters.

As the armies and weapons become increasingly powerful, the care of the sick and wounded became more complex. Military medicine perfected knowledge and skills in taking care of wounded at the battlefield and preventing loss of life. Epidemics in armies have killed more troops than have weapons, so treating and preventing disease are a part of military medicine. Many medical discoveries have been implemented in the army and later in civil society, including surgery, vaccination, antibiotics, nutrition, and others.

The Roman Empire developed military medicine as its professional armies spread across the known world. The Roman army included physicians to provide medical care for the legions, beginning with ensuring that only the best (and most intelligent) candidates were recruited. Once in service, the military medical corps strove to ensure the general health of the soldier by a continuous stress of hygiene. The design of legion fortifications and encampments ensured a healthy environment for the troops. Following the destruction of Rome and later the Eastern Empire, the Roman military medical tradition disappeared. Military medicine during the Middle Ages was relatively primitive.

Jean Henri Dunant, a young Swiss businessman, arrived in Solferino, Italy, on the evening of the battle fought on June 24, 1859, between the French-Sardinian allies against the Austrian army. Some 38,000 injured, dying, and dead soldiers remained on the battlefield, with little attempt to provide care. Dunant took the initiative to organize volunteers from the local civilian population, especially the women and girls, to provide assistance to the injured and sick soldiers. He organized the purchase of needed materials and helped erect makeshift hospitals, providing care for all without regard to their affiliation in the conflict, along with volunteer doctors and Austrian doctors captured by the French.

After returning to Geneva, Dunant published a book about his experience, *A Memory of Solferino*, describing the battle, its costs, and the chaos afterwards. He proposed that in the future a neutral organization should be established to provide care to wounded soldiers. His work led to the First Geneva Convention on the treatment of noncombatants and prisoners of war, followed by the foundation of the International Committee of the Red Cross in 1863, now ratified by 194 countries. He was awarded the first Nobel Prize for Peace in 1901.

The Crimean War was a medical disaster for the British Army with higher mortality from disease than from battle largely as a result of poorly organized sanitation, supply, and medical services. Mortality rates among British amputees in the Scutari Hospital averaged nearly 30 percent. Of every 100 men in the French forces admitted to military hospitals, 42 percent died — a hospital mortality rate equivalent to that of the Middle Ages. Florence Nightingale with her 18 trained nurses in November 1854 after the battle of Balaklava introduced basic standards of hygiene, nutrition and sanitation, and administration in the British military hospitals. Upon her arrival, Nightingale reported a hospital mortality rate at Scutari of 44 percent. As a result of her efforts, the rate dropped to 2 percent by the end of the war.

Nightingale's work made an enormous contribution to knowledge and practice of hospital organization and management. On the opposing side of the same Crimean War, Nikolai Perogov, a military surgeon in the Russian czarist army, developed rectal anesthesia for field surgery, triage of wounded by degree of severity, and hygiene of wounds. Perogov also defined improved systems for management of the wounded in war theaters, which had applicability in civilian hospitals. The French army in World War I further developed the triage system of casualty clearance now used worldwide in military and disaster situations.

Nutrition of sailors on long sea voyages and the epidemiologic study of scurvy, followed a century later by the work on beriberi, were important steps in identifying nutrition and its importance to public health. Bismarck's establishment of national health insurance and other benefits for workers was partly based on the need to improve the health of the general population in order to build mass armies of healthy conscripts (see Chapter 13). During conscription to the U.S. Army in World War I, high rates of rejection of draftees as medically unfit for military service raised concerns for national health standards. Finding high rates of goiter in the draftees led to efforts to identify high-risk areas and to reduce iodine deficiency in the civilian population by iodization of salt.

In the wake of World War I, a massive pandemic of influenza killed some 20 million people. The Spanish flu pandemic lasted from 1918 to 1919. Older estimates say it killed 40 to 50 million people, while current estimates say 50 to 100 million people worldwide died in this pandemic, described as "the greatest medical holocaust in history" and may have killed as many people as the Black Death. The Spanish flu, closely following the huge losses of World War I, was to a large degree spread in the close quarters of army camps and mass movement of troops, with a high percentage of the deaths occurring among young men, the group most affected by the war itself.

Epidemics of louse-borne typhus in Russia following the war and the Russian Revolution contributed to the chaos of the period. This prompted Lenin's statement "Either socialism will conquer the louse, or the louse will conquer socialism." In World War II, sulfa drugs, antimalarials, and antibiotics made enormous contributions to the Allied war effort and later to general health care and preserving the health of the population. Lessons learned in war for protection of soldiers from disease and treatment of burns, crash injuries, amputations, battle fatigue, and many other forms of trauma were brought back to civilian health systems. Much of modern medical technology was first developed for or tested by the military. As an example, sonar radio wave mechanisms developed to detect submarines were adapted after World War II as ultrasound, now a standard noninvasive instrument in medical care.

In the twentieth century, the destructiveness of war increased enormously with chemical, biological, and nuclear weapons of mass destruction. The Nuremberg Trials addressed the Holocaust and unethical medical experimentation of the Nazi military on civilian and

military prisoners. The International Declaration of Human Rights (1948) and the Helsinki Declaration (1964) set new standards for medical and research ethics, with important implications for public health.

The brutalities of wars against civilian populations have tragically recurred even near the end of the twentieth century in genocidal warfare in Iraq, Rwanda, and the former Yugoslavia. Those tragedies produced massive casualties and numerous refugees, with resultant public health crises requiring intervention by local and international health agencies. International and national public health agencies have major responsibility for prevention of extension of some of the mass tragedies of the twentieth century recurring, perhaps on a bigger scale in the twenty-first century with the spread of the potential for chemical, biological, and potentially nuclear terrorism.

INTERNATIONALIZATION OF HEALTH

Cooperation in health has been a part of international diplomacy from the first international conference on cholera in 1851 in Cairo to the health organization of the League of Nations after World War I, and into modern times. Following World War II, international health began to promote widespread application of public health technology, such as immunization, to developing countries. The World Health Organization (WHO) was founded in 1946 with a charter defining health as "the complete state of physical, social and mental well-being, and not merely the absence of disease."

The tradition of international cooperation is continued by organizations such as WHO, the International Red Cross/Red Crescent (IRC), United Nations Children's Fund (UNICEF), and many others. Under the leadership of WHO, eradication of smallpox by 1977 was achieved through united action, showing that major threats to health could be controlled through international cooperation. The potential for eradication of polio further demonstrates this principle.

The global spread of disease has taken enormous tolls of human life with global proportions and the threat continues in the twenty-first century. Globalization of public health threats can emerge and spread rapidly, as seen with the HIV pandemic since the 1980s and SARS in 2003. More recently, concerns have grown for potentially devastating pandemic influenza, such as the H5N1 virus strain known as avian influenza. Chronic diseases, the commonest causes of mortality and disability in the industrialized countries in the latter half of the twentieth century, are now also predominant in most developing countries with growing middle-class communities. Tobacco use, obesity, diabetes, heart disease, and cancer are among the leading causes of morbidity and mortality in the contemporary world. The toll of violence, often overlooked as a public health problem, cannot be overstated. Many other factors affect health globally, including environmental degradation with global warming, accumulating ozone and toxic wastes, acid rain, nuclear accidents, loss of nature reserves such as the Amazon basin rain forests, and the human tragedy of chronic poverty of many developing countries. Global health issues are by their very nature beyond the capacity of individual or even groups of countries to solve. They require organized common efforts of governments, international agencies, and nongovernmental organizations to cooperate with each other, with industry, and with the media to bring about change and reduce the common hazards that abuse of the environment and social gaps cause.

Tobacco is the leading preventable risk factor for premature mortality worldwide. Estimates of 5 million annual deaths attributable to smoking do not adequately measure the impact of the tobacco pandemic, as tobacco use contributes and exists as a co-morbidity factor to a very wide spectrum of disease and has justly become a major issue of public health. Over half of the estimated 650 million people currently smoking will die of effects of this addiction and if current smoking patterns continue, it will cause more than 10 million deaths yearly by 2020. Recognition of tobacco control is gaining support of researchers, medical professionals, politicians, and communities around the world. The CDC sees recognition of tobacco as a public health hazard as one of the greatest public health achievements of the twentieth century in the United States. The WHO's Framework Convention on Tobacco Control adopted by the 56th World Health Assembly in 2003 placed elimination of tobacco use as one of the greatest public health challenges, but one far from fruition.

Bringing health care to all the people is as great a challenge as feeding a rapidly growing global population. Successes in eradication of smallpox and control of many other diseases by public health measures show the potential for concerted international cooperation and action targeted to specific objectives that reduce disease and suffering.

THE EPIDEMIOLOGIC TRANSITION

As societies evolve, so do patterns of disease. These changes are partly the result of public health and medical care but just as surely are due to improved standards of living, nutrition, housing, and economic security, as well as changes in fertility and other family and social factors. As disease patterns change, so do appropriate strategies for intervention.

During the first half of the twentieth century, infectious diseases predominated as causes of death even in the developed countries. Since World War II, a major shift in epidemiologic patterns has taken place in the industrialized

countries, with the decline in infectious diseases and an increase in the noninfectious diseases as causes of death. Increases in longevity have occurred primarily from declining infant and child mortality, improved nutrition, control of vaccine-preventable diseases, and the advent of antibiotics for treatment of acute infectious diseases. The rising incidence of cardiovascular diseases and cancer affects primarily older people, leading to a growing emphasis in epidemiologic investigations on causative risk factors for these noninfectious diseases.

Studies of the distribution of noninfectious diseases in specific groups go back many centuries when the Romans reported excess death rates among specific occupational groups. These studies were updated by Ramazzini in the early eighteenth century. As noted earlier, in eighteenth-century London, Percival Potts documented that cancer of the scrotum was more common among chimney sweeps than in the general population. Nutritional epidemiologic studies, from Lind on scurvy among sailors in 1747 to Goldberger on pellagra in the southern United States in 1914, focused on nutritional causes of noninfectious diseases in public health.

Observational epidemiologic studies of "natural experiments" produced enormously important data in the early 1950s, when pioneering investigators in the United Kingdom, Richard Doll, Austin Bradford Hill, and James Peto, demonstrated a relationship between tobacco use and lung cancer. They followed the mortality patterns of British physicians from different causes, especially lung cancer. They found that mortality rates from lung cancer were 10 times higher in smokers than in nonsmokers. Epidemiologic studies pointing to the relationship of diet and hypertension with cardiovascular diseases also provided critically important material for public health policy, and raised public concern and consciousness in western countries of the impact of lifestyle on public health. In this new era of public health, the complementary relationship between miasma and germ theories is recognized (Box 1.10). These issues are discussed subsequently throughout this book.

In the mid-twentieth century, while communicable diseases were coming under control, risks related to modern living developed; cardiovascular disease, trauma, cancer, and other chronic diseases have become the predominant causes of premature death. These are more complex than the infectious diseases, both in causation and the means of prevention. Still, public health interventions have shown surprising success in combating this set of mortality patterns, with a combination of improved medical care and activities under the general title of health promotion.

At the beginning of the twenty-first century, the need to link public health with clinical medical care and organization of services is increasingly apparent. The decline in coronary heart disease mortality is accompanied by a slow increase in morbidity, and recent epidemiologic evidence shows new risk factors not directly related to

Box 1.10 Complementary Contributions of the Miasma and Germ Theories

The miasma theory (i.e., the concept that airborne vapors or "miasmata" caused most diseases) in the mid-nineteenth century competed with the germ theory (i.e., specific microorganisms cause specific diseases). The latter gained pre-eminence among scientists and biological sciences, yet the miasma theory was the basis for action by sanitary reformers. Miasma explained why cholera and other diseases were epidemic in places where the undrained sewage water was foul-smelling. Their endeavors led to improved sanitation systems, which led to decreased episodes of cholera. The connection between dirtiness and diseases led to public health reforms and encouraged cleanliness. The miasma theory was consistent with the observations that disease was associated with poor sanitation and foul odors, and that sanitary improvements reduced disease.

These two theories continued to compete until today. The wider version of the miasma theory is that environmental and social conditions are the main factors in disease, in contrast to the more biologically oriented approach of germ theory of infectious diseases and as applied to chronic disease related to toxins (e.g., smoking) or nutritional indicators (e.g., blood lipids and micronutrient deficiency conditions). Clearly, both are operative, with improved infectious disease control and environmental and social conditions all contributing to improved longevity and reduced burden of many diseases. However, large gaps remain between rich and poor as a result of differential social, economic, and cultural differences.

In 2007, the *British Medical Journal* conducted an opinion survey of the most important medical innovations of all time. The clear winner was the "sanitary revolution as greatest medical advance since 1840." The problem remains today that millions of people die annually from lack of modern sanitation of safe drinking water and poor sewage and solid waste disposal. Other large-scale killers are infectious diseases for which excellent vaccines or other management tools exist.

Both the germ and miasma ideas are important elements of global health. Even in developed countries, management of infectious diseases is still a major public health issue, and includes the annual loss of life from influenza, pneumonia, medically related diseases such as multidrug-resistant tuberculosis, and the rise of drug-resistant organisms easily controlled by antibiotics a short generation ago.

Sources: Ferriman, A. 2007. BMJ readers choose the "sanitary revolution" as greatest medical advance since 1840. *British Medical Journal*, 334:111. Mackenbach, J. P. 2007. Sanitation: pragmatism works. *British Medical Journal*, 334(suppl 1):s17.

lifestyle, but requiring longitudinal preventive care to avert early recurrence and premature death. Progress continues into the twenty-first century as new challenges arise.

ACHIEVEMENTS OF PUBLIC HEALTH IN THE TWENTIETH CENTURY

The foundations of public health organization were laid in the second half of the nineteenth and first half of the twentieth centuries. Water sanitation, waste removal, and food control developed at municipal and higher levels of government, establishment of organized local public health offices with state and federal grants, and improved vaccination technology all contributed to the control of communicable diseases. Organized public health services implemented the regulatory and service components of public health in developed countries, with national standards for food and drug safety, state licensing, and discipline in the health professions.

At the beginning of the twentieth century, there were few effective medical treatments for disease, but improved public health standards resulted in reduced mortality and increased longevity. As medical technology improved following World War II with antibiotics, antihypertensives, and antipsychotic therapeutic agents, the focus was on curative medical care, with a widening chasm between public health and medicine. In our time, a new interest in the commonality between the two is emerging as new methods of organizing and financing health care develop, to contain the rising costs of health care and increase utilization of preventive medicine.

National and state efforts to promote public health during the twentieth century widened in scope of activities and financing programs. This required linkage between governmental and nongovernmental activities for effective public health services. Dramatic scientific innovations brought vaccines and antibiotics which along with improved nutrition and living standards, helped to control infectious disease as the major cause of death. In the developed countries, the advent of national or voluntary health insurance on a wide scale opened access to health care to high percentages of the population.

The modern era of public health from the 1960s to today has brought a new focus on noninfectious disease epidemiology and prevention. Studies of the impact of diet and smoking on cardiovascular diseases and smoking on lung cancer isolated preventable risks for chronic disease. As a result of these and similar studies of disease and injury related to the environment, modern public health has, through health promotion and consumer advocacy, played a significant role in mortality and morbidity reduction for a spectrum of diseases. For prevention of premature disease and death, more comprehensive approaches will be needed by public health and health care providers than have been developed to date.

The twentieth century saw great achievements in public health in the industrialized countries, indeed throughout the world. The Centers for Disease Control reviewed these achievements in a series of publications in 1999 which represent the potential for public health and if not a universal "gold standard," at least a well-documented set of achievements and potential for public health everywhere (see Box 1.11).

The dream of international and national health agencies to achieve *Health for All* faces serious obstacles of inequities, lack of resources, distortions with overdevelopment of some services at the expense of others, and competing priorities. Managing health care to use resources more effectively is now a concern of every health professional. At the same time, public expectations are high for unlimited access to care, including the specialized and highly technical services that can overwhelm budgetary and personnel resources available. All nations, wealthy or poor, face the problem of managing limited resources. How that will be achieved is part of the challenge we discuss as the New Public Health.

Box 1.11 Ten Great Achievements of Public Health in the United States in the Twentieth Century

During the twentieth century, the health and life expectancy in the United States improved dramatically. Since 1900, average lifespan lengthened by >30 years; 25 years of this gain is attributable to advances in public health. *Morbidity and Mortality Weekly Report* (MMWR) profiled 10 public health achievements in a series of reports published in 1999. This reflects similar public health achievements in many industrialized countries.

1. Control of infectious disease
2. Vaccination
3. Motor vehicle safety
4. Safer workplaces
5. Decline in deaths from coronary heart disease, strokes
6. Safer and healthier foods
7. Healthier mothers and babies
8. Family planning
9. Fluoridation of drinking water
10. Recognition of tobacco as a health hazard

Source: CDC. Ten Great Public Health Achievements — United States, 1900–1999. *Morbidity and Mortality Weekly Reports*, 48(12):241–243. www.cdc.gov/mmwr

CREATING AND MANAGING HEALTH SYSTEMS

Provision of medical care to the entire population is one of the great challenges of public health. Governments of all political stripes are active in the field of health policy, as insurers, providers, or regulators of health care. As will be discussed in subsequent chapters, nations have many reasons to ensure health for all, just as they promote universal education and literacy. National interests in the late nineteenth and early twentieth centuries were defined to include having healthy populations, especially for workers and soldiers, and for national prestige. Responsibility for the health of a nation included measures for prevention of disease, but also financing and prepayment for medical and hospital care. National policies gradually took on measures to promote health, structures to evaluate health of the nation, and modification of policies to keep up with changing needs.

The health of a population requires access to medical and hospital services as well as preventive care, a healthy environment, and a health promotion and policy orientation. Greek and Roman cities appointed doctors to provide free care for the poor and the slaves. Medieval guilds provided free medical services to their members. In 1883, Germany introduced compulsory national health insurance to ensure healthy workers and army recruits, which would provide a political advantage. In 1911, Britain's Chancellor of the Exchequer, Lloyd George, instituted the National Insurance Act, providing compulsory health insurance for workers and their families. In 1918, following the October Revolution, the Soviet Union created a comprehensive state-operated health system with an emphasis on prevention, providing free comprehensive care in all parts of the country.

During the 1920s, national health insurance was expanded in many countries in Europe. Following the Great Depression of the 1930s and hopes raised by the victory in World War II, important social and health legislation was enacted to provide health care to the populations of Britain, Canada, and the United States. In Britain the welfare state including the National Health Service (NHS) was developed by the Labour Government. In Canada, a more gradual development took place in the period from 1940–1970, including the establishment of national pensions and a national health insurance program. In the United States, social legislation has been slow in coming following the defeat of national health insurance legislation in Congress in 1946 and long-standing ideological opposition to "socialized medicine," but in 1965, universal coverage of the population over age 65 (Medicare) was instituted and coverage for the poor under Medicaid soon followed. Inadequate coverage of workers and low-income American families is still a serious problem. In the latter part of the twentieth century, virtually every country recognizes the importance of health for the social and economic well-being of its population.

The term *health systems* may imply a formalized structure or a network of functions that work together to meet the needs of a population through health insurance or health service systems. Private health insurance is still the dominant mode in the United States, but the elderly and the poor are covered by government health insurance (see Chapter 13). The American public health community is currently seeking means to achieve universal health coverage. Prepayment for health is financed through general tax revenues in many countries, and in others through payment by workers and employers to social security systems. Both developed and developing countries are involved in financing health care as well as research and training of health professionals.

Industrialized countries share increasing concerns of cost escalation, with health expenditure costs hindering general economic growth. While health care is a large-scale employer in all developed countries, high and rising expenditures for health, reaching 16 percent of GDP in the United States and around 10 percent in many other western countries, is a major factor in stimulating health care reform. Many countries are struggling to keep up with rising costs and competition from other social needs, such as education, employment, and social welfare, all of which are important for national health and well-being. Some economic theories allocate no economic value to a person except as an employee and a consumer. Liberal and social democratic political philosophies advocate an ethical concern and societal responsibility for health. Both approaches now concur that health has social and economic value. The very success of public health has produced a large increase in the percentage of the elderly in the population, raising ethical and economic questions regarding health care consumption, allocation of services, and social support systems.

For developing countries, providing health care for the entire population is a distant dream. Limited resources and overspending on high-technology facilities in larger cities leave little funding for primary care for the rural and urban poor. Despite this, there has been real progress in implementing fundamental services such as immunization and prenatal care. Still, millions of preventable deaths occur annually because of lack of basic primary care programs.

SUMMARY

The history of public health is directly related to the evolution of thinking about health. Ancient societies in one way or another realized the connection between sanitation and health and the role of personal hygiene, nutrition, and fitness. The sanctity of human life (*Pikuah Nefesh*) established an overriding human responsibility to save life

derived from Mosaic Law from 1500 BCE. The scientific and ethical basis of medicine was also based on the teachings of Hippocrates in the fourth century BCE. Sanitation, hygiene, good nutrition, and physical fitness all had roots in ancient societies including obligations of the society to provide care for the poor. These ethical foundations support efforts to preserve life even at the expense of other religious or civil ordinances.

Social and religious systems linked disease to sin and punishment by higher powers, viewed investigation or intervention by society (except for relief of pain and suffering) as interference with God's will. Childbirth was associated with pain, disease, and frequent death as a general concept of "in sorrow shall you bring forth children." Health care was seen as a religious charitable responsibility to ease the suffering of sinners.

The clear need and responsibility of society to protect itself by preventing entry or transmission of infectious diseases was driven home by pandemics of leprosy, plague, syphilis, smallpox, measles, and other communicable diseases in the Middle Ages. The diseases themselves evolved, and pragmatic measures were gradually found to control their spread, including isolation of lepers, quarantine of ships, and closure of public bath houses. Epidemiologic investigations of cholera, typhoid, occupational diseases, and nutritional deficiency disorders in the eighteenth and nineteenth centuries began to show causal relationships and effective methods of intervention before scientific proof of causation was established. Even in contemporary times, public health practice continues on a pragmatic basis, often before full scientific basis of the causation of many diseases has been worked out. Public health organizations to ensure basic community sanitation and other modalities of prevention evolved through the development of local health authorities, fostered, financed, and supervised by civic, state, or provincial and national health authorities as governments became increasingly involved in health issues.

Freeing human thought from restrictive dogmas which limited scientific exploration of health and disease fostered the search for the natural causation of disease. This was of paramount importance in seeking interventions and preventive activities. This concept, first articulated in ancient Greek medicine, provided the basis for clinical and scientific observations leading to the successes of public health over the past two centuries. The epidemiologic method led to public health interventions before the biological basis of disease was determined. Sanitation to prevent disease was accepted in many ancient societies, and codified in some as part of civil and religious obligations. Lind's investigation of scurvy, Jenner's discovery of vaccination to prevent smallpox, and Snow's investigation of cholera in London demonstrated disease causation in modern scientific epidemiologic terms, and were accepted despite lack of contemporary biochemical or bacteriologic proof. They helped to formulate the core methodology of public health.

Public health has developed through pioneering epidemiologic studies, devising forms of preventive medicine, and community health promotion. Reforms pioneered in many areas, from abolition of slavery and serfdom to provision of state-legislated health insurance, have all improved the health and well-being of the general population. In the last years of the twentieth century, the relationship between health and social and economic development gained recognition internationally. The twentieth century has seen a dramatic expansion of the scientific basis for medicine and public health. Immunology, microbiology, pharmacology, toxicology, and epidemiology have provided powerful tools and resulted in improved health status of populations. New medical knowledge and technology have come to be available to the general public in many countries in the industrialized world through the advent of health insurance. In this century, virtually all industrialized countries established systems of assuring access to care for all the population as essential for the health of the individual and the population.

Major historical concepts have had profound effects on the development of public health. Sickness as punishment for sin prevented attempts to control disease over many centuries. This mentality persists in modern times by "blaming the victim"; AIDS patients are seen as deserving their fate because of their behavior, workers are believed to become injured because of their own negligence, and the obese person and the smoker are believed to deserve their illnesses because of weakness in the way they conduct their lives. The sanctity of human life, improving the world, and human rights are fundamental to the ethics and values of public health, as is charity in care in which there is a societal and professional responsibility for kindness and relief of suffering. Ethical controversies are still important in many diverse areas such as universal health insurance, food fortification, fluoridation of water supplies, managed care, reproductive health, cost–benefit analysis, euthanasia, and care of sex workers and prisoners and many others.

Acceptance of the right to health for all by the founders of the United Nations and the WHO added a universal element to the mission of public health. This concept was embodied in the constitution of the WHO and given more concrete form in the *Health for All* concept of Alma-Ata, which emphasized the right of health care for everyone and the responsibility of governments to ensure that right. This concept also articulates the primary importance of prevention and primary care, which became a vital issue in competition for resources between public health and hospital-oriented health care.

The lessons of history are important in public health. Basic issues of public health need to be revived because new challenges for health appear and old ones re-emerge. The philosophical and ethical basis of modern public health is a belief in the inherent worth of the individual and his or her human right to a safe and healthful environment.

The health and well-being of the individual and the community are interdependent. Investment in health, as in education, is a contributor to economic growth, as healthy and educated individuals contribute to a creative and economically productive society.

The New Public Health is derived from the experience of history. Organized activity to prevent disease and promote health had to be relearned from the ancient and post-industrial revolution worlds. As the twenty-first century begins, we must learn from a wider framework how to use all health modalities, including clinical and prevention-oriented services, to effectively and economically preserve, protect, and promote the health of individuals and of greater society. The New Public Health, as public health did in the past, faces ethical issues which relate to health expenditures, priorities, and social philosophy. Throughout the course of this book, we discuss these issues and attempt to illustrate a balanced, modern approach toward the New Public Health.

HISTORICAL MARKERS

3000 BCE	Dawn of Sumerian, Egyptian, and Minoan cultures — drains, flush toilets
2000 BCE	Indus valley — urban society with sanitation facilities
1700 BCE	The Code of Hammurabi — rules governing medical practice
1500 BCE	Mosaic Law — personal, food, and camp hygiene, segregating lepers, overriding duty of sanctity of human life (*Pikuah Nefesh*) and improving the world (*Tikun Olam*) as religious imperatives
400 BCE	Greece — personal hygiene, fitness, nutrition, sanitation, municipal doctors, occupational health; Hippocrates — clinical and epidemic observation and environmental health
500 BCE to 500 CE	Rome — aqueducts, baths, sanitation, municipal planning, and sanitation services, public baths, municipal doctors, military, and occupational health
170 CE	Galen — physiology, anatomy, humors dominated western medicine until 1500 CE
500–1000	Europe — destruction of Roman society and the rise of Christianity; sickness as punishment for sin; mortification of the flesh, prayer, fasting, and faith as therapy; poor nutrition and hygiene, pandemics; anti-science; care of the sick as religious duty
700–1200	Islam — preservation of ancient health knowledge, schools of medicine, Arab–Jewish medical advances (Ibn Sinna and Maimonides)
1000+	Universities and hospitals in Middle East and Europe
1000+	Rise of cities, trade, and commerce, craft guilds, municipal hospitals
1096–1272	Crusades — contact with Arabic medicine, hospital orders of knights, leprosy
1268	Roger Bacon publishes treatise on use of eyeglasses to improve vision
1348	Venice — board of health and quarantine established
1348–1350	Black Death — origins in Asia, spread by armies of Genghis Khan, world pandemic kills 60 million in fourteenth century, one-third to one-half of the population of Europe
1300	Pandemics — bubonic plague, smallpox, leprosy, diphtheria, typhoid, measles, influenza, tuberculosis, anthrax, trachoma, scabies, and others until eighteenth century
1400–1600	Renaissance and enlightenment, decline of feudalism, rise of urban middle class, trade, commerce, exploration, new technology, arts, science, anatomy, microscopy, physiology, surgery, clinical medicine, hospitals (religious, municipal, voluntary)
1518	Royal College of Physicians founded in London
1532	Bills of Mortality published
1546	Girolamo Fracastorus publishes *De Contagione* — the germ theory
1562–1601	Elizabethan Poor Laws — responsibility for the poor on local government
1628	William Harvey publishes findings on circulation of the blood
1629	London Bills of Mortality specify causes of death
1639	Massachusetts law requires recording of births and deaths
1660s	Leyden University strengthens anatomical education
1661	John Graunt founds medical statistics
1661	Rene Descartes publishes first treatise on physiology
1662	Royal Society of London founded by Francis Bacon
1665	Great Plague of London
1673	Antony van Leeuwenhoek — microscope, observes sperm and bacteria
1667	Pandemics of smallpox in London; pandemic of malaria in Europe
1687	William Petty publishes *Essays in Political Arithmetic*
1700	Bernardino Ramazzini publishes compendium of occupational diseases
1701	London — 75% of newborns die before fifth birthday
1701	Variolation against smallpox practiced in Constantinople, isolation practiced in Massachusetts
1710	English Quarantine Act
1720+	London — voluntary teaching in hospitals; Guy's, Westminster
1721	Lady Mary Montagu introduces inoculation for smallpox to England
1730	Science and scientific medicine; Rights of Man, encyclopedias, agricultural and industrial revolutions, population growth — high birth rates, falling death rates
1733	Obstetrical forceps invented
1733	Stephen Hales measures blood pressure
1747	James Lind — case control study of scurvy in sailors
1750	British naval hospitals established
1750	John Hunter establishes modern surgical practice and teaching
1752	William Smellie publishes textbook of midwifery
1762	Jean Jacques Rousseau publishes *Social Contract*
1775	Percival Pott investigates scrotal cancer in chimney sweeps
1777	John Howard promotes prison and hospital reform in England

1779	Johann Frank promotes Medical Police in Germany
1785	William Withering — discovers foxglove (*Digitalis*) treatment of dropsy
1788	Legislation to protect boys employed as chimney sweepers
1796	Edward Jenner — vaccinates 24 children against smallpox from milkmaid's cowpox pustules
1796	British Admiralty adopts daily issue of lime juice for sailors at sea to prevent scurvy
1797	Massachusetts legislation permitting local boards of health
1798	Philippe Pinel removes chains from insane in Bicetre Asylum
1798	President John Adams signs law for care of sick and injured seamen, establishing marine hospital service, later becoming U.S. Public Health Service (1912)
1800	Britain and U.S. — Municipal Boards of Health
1800	Vaccination adopted by British army and navy
1800	Adam Smith, Jeremy Bentham — economic, social philosophers
1801	Vaccination mandatory in Denmark, local eradication of smallpox
1801	First national census, United Kingdom
1804	Modern chemistry established — Humphrey Davey, John Dalton
1807	Abolition Act — mandates eradication of international slave trade by the Royal Navy
1827	Carl von Baer in St. Petersburg establishes science of embryology
1834	Poor Law Amendment Act documents harsh state of urban working class in United States
1837	United Kingdom National Vaccination
1830s–1840s	Sanitary and social reform, growth of science; voluntary societies for reform, boards of health, mines and factory acts — improving work conditions
1842	Edwin Chadwick — Sanitary Commission links poverty and disease
1844	Horace Wells — anesthesia in dentistry, then surgery
1848	U.K. Parliament passes Public Health Act establishing the General Board of Health
1850	Massachusetts — Shattuck Report of Sanitary Commission
1852	Adolph Chatin uses iodine for prophylaxis of goiter
1854	John Snow — waterborne cholera in London: the Broad Street pump
1854	Florence Nightingale, modern nursing and hospital reform — Crimean War
1855	London — mandatory filtration of water supplies and consolidation of sanitation authorities
1858	Louis Pasteur proves no spontaneous generation of life
1858	Rudolph Virchow publishes *Cellular Pathology*; pioneer in political–social health context
1858	Public Health and Local Government Act and Medical Act in United Kingdom — local health authorities and national licensing of physicians
1859	Charles Darwin publishes *On the Origin of Species*
1861	Emancipation of the serfs in Russia
1861	Ignaz Semmelweiss publishes *The Cause, Concept and Prophylaxis of Puerperal Fever*
1862	Louis Pasteur publishes findings on microbial causes of disease
1862	Florence Nightingale founds St. Thomas' Hospital School of Nursing
1862	Sanitary Commission during U.S. Civil War
1862	Emancipation of slaves in United States
1864	Boston bans use of milk from diseased cows
1864	Russia — rural health as tax-supported local service through Zemstvos
1864	First International Geneva Convention and founding of International Committee of the Red Cross
1866	Gregor Johann Mandel, Czech monk, basic laws of heredity, basis of genetics
1867	Joseph Lister describes use of carbolic spray for antisepsis
1869	Dimitri Ivanovitch Mendeleev — periodic tables
1872	American Public Health Association founded
1872	Milk stations established in New York immigrant slums
1876	Robert Koch discovers anthrax bacillus
1876	Neisser discovers *Gonococcus* organism
1879	U.S. National Board of Health established
1879	U.S. Food and Drug Administration established
1880	Typhoid bacillus discovered (Laveran); leprosy organism (Hansen); malaria organism (Laveran)
1882	Robert Koch discovers the *Tuberculosis* organism, tubercle bacillus
1883	Otto von Bismarck introduces social security with workmen's compensation, national health insurance for workers and their families in Germany
1883	Robert Koch discovers bacillus of cholera
1883	Louis Pasteur vaccinates against anthrax
1885	Takaki in Japanese navy describes beriberi and recommends dietary change
1884	*Diphtheria*, *Staphylococcus*, *Streptococcus*, *Tetanus* organisms identified
1885	Pasteur develops rabies vaccine; Escherich discovers *coli* bacillus
1886	Karl Fraenkel discovers *Pneumococcus* organism
1887	Malta fever or brucellosis (Bruce) and chancroid (Ducrey) organisms identified
1887	U.S. National Institutes of Health founded
1890	Anti-tetanus serum (ATS)
1892	Gas gangrene organism discovered by Welch and Nuttal
1894	Plague organism discovered (Yersin, Kitasato); botulism organism (Van Ermengem)
1895	Louis Pasteur develops vaccine for rabies
1895	Wilhelm Roentgen — discovers electromagnetic waves (x rays) for diagnostic imaging
1895	Emil von Behring develops diphtheria vaccine (Nobel Prize, 1901)
1897	London School of Hygiene and Tropical Medicine founded
1897	Felix Hoffman — synthesizes acetylsalicylic acid (aspirin)
1905	Abraham Flexner — major report on medical education in United States
1905	Workman's Compensation Acts in Canada
1906	U.S. Pure Food and Drug Act passed by Congress
1910	Paul Ehrlich — chemotherapy use of arsenical salvarsan for treatment of syphilis
1911	Lloyd George, United Kingdom compulsory health insurance for workers

1911	Kasimir Funk investigates "vital amines" and names them vitamins
1912	Health insurance for industrial workers in Russia
1912	U.S. Children's Bureau and U.S. Public Health Service established
1914	Joseph Goldberger investigates cause and prevention of pellagra
1915	Johns Hopkins and Harvard Schools of Public Health founded
1915	Tetanus prophylaxis and antitoxin for gas gangrene
1918–1919	Pandemic of Spanish flu (influenza) kills some 20 million people
1904	Ivan Petrovitch wins Nobel Prize for work in conditioned reflexes, neurophysiology
1918	Nikolai Semashko introduces U.S.S.R. national health plan
1921	Frederick Banting and Charles Best discover insulin in Toronto
1923	Health Organization of League of Nations established
1924	David Cowie promotes widespread ionization of salt in the U.S.; Morton's iodized salt popularized in North America
1926	Pertussis vaccine developed
1928	Alexander Fleming discovers penicillin
1928	George Papanicolaou develops Pap smear for early detection of cancer of cervix
1929–1936	The Great Depression — widespread economic collapse, unemployment, poverty, and social distress in industrialized countries
1930	U.S. Food and Drug Administration established
1935	President Roosevelt — Social Security Act and the New Deal in the United States
1940	Charles Drew describes storage and use of blood plasma for transfusion
1941	Norman Gregg reports rubella in pregnancy causing congenital anomalies
1939–1945	World War II, food fortification in United States, Canada, and Britain; U.K. National Hospital Service — wartime nationalization of hospitals; (William) Beveridge Report in the United Kingdom — the "Welfare State" (1942); U.S. National Centers for Disease Control established; U.S. Emergency Maternity and Infant Care for families of servicemen; U.S.S.R. wartime emergency medical structure; Nazi Holocaust of 6 million Jews and many others
1945	Grand Rapids MI; Newburgh, NY; and Brantford, Ontario — first cities to fluoridate water supplies
1946	World Health Organization founded
1946	National health insurance defeated in U.S. Congress
1946	U.S. Congress Hill–Burton Act supports local hospital construction up to 4.5 beds/1000 population
1946	Tommy Douglas — Saskatchewan provincial hospital insurance plan
1947	Nuremberg Doctors Trial of Nazi crimes against humanity
1948	International Declaration of Human Rights
1948	United Kingdom establishes National Health Service
1953	James Watson and Francis Crick discover the double helix structure of DNA (Nobel Prize 1962)
1954	Framingham study of heart disease risk factors
1954	Richard Doll reports on link of smoking and lung cancer
1954	Jonas Salk's inactivated poliomyelitis vaccine licensed
1955	Michael Buonocore discovers dental sealants
1956	Gregory Pincus reports first successful trials of birth control pills
1960	Albert Sabin — live poliomyelitis vaccine licensed
1961	American Academy of Pediatrics recommends routine vitamin K for all newborns
1963	Measles vaccine licensed
1964	U.S. Surgeon General's Report on Smoking (Luther Terry)
1965	United States passes Medicare for the elderly, Medicaid for the poor
1966	U.S. National Traffic and Motor Vehicle Safety Act
1967	Mumps vaccine licensed
1970	Rubella vaccine licensed
1971	Canada has universal health insurance in all provinces
1974	LaLonde Report — New Perspectives on the Health of Canadians
1977	WHO adopts Health for All by the Year 2000
1977	Last known outbreak of smallpox reported in Somalia
1978	Alma-Ata Conference on Primary Health Care
1978	Hepatitis B vaccine licensed
1979	Canada adopts mandatory vitamin/mineral enrichment of foods
1979	WHO declares eradication of smallpox achieved
1981	First recognition of cases of acquired immune deficiency syndrome (AIDS)
1985	WHO European Region Health Targets
1985	*Haemophilus influenzae* b (Hib) vaccine licensed by FDA
1985	Luc Montaignier publishes genetic sequence of HIV
1988	American College of Obstetricians, Gynecologists recommends annual pap smears for all women
1989	WHO targets eradication of polio by the year 2000
1989	Warren and Marshall — *Helicobacter pylori* as treatable cause of peptic ulcers
1989	International Convention on the Rights of the Child
1990	World Summit on Children, New York
1990	World Conference on Education for All, Jomtien
1990	W. F. Anderson performs first successful gene therapy
1990	Newly emerging and reemerging diseases (HIV, Marburg, Ebola, cholera, mad cow disease, tuberculosis) and multidrug-resistant organisms
1991	Folic acid proven to prevent neural tube defects
1992	United Nations Conference on Environment and Development, Rio de Janeiro
1992	International Conference on Nutrition
1993	World Conference on Human Rights, Vienna
1993	*World Development Report: Investing in Health* published by World Bank
1993	Russian Federation approves compulsory national health insurance
1994	International Conference on Population and Development, Cairo
1994	Clinton National Health Insurance plan defeated in U.S. Congress
1995	World Summit for Social Development, Copenhagen

1995	United Nations Fourth World Conference on Women, Beijing
1996	Second United Nations Conference on Human Settlement (Habitat II), Istanbul
1996	Explosive growth of managed care plan coverage in the United States
1997	Legal suits for damages against tobacco companies for costs of health effects of smoking, 33 states in the United States and other countries
1998	Clinton proposed legislation on patients' rights in managed care
1998	FDA approves rotavirus vaccine
1998	WHO *Health for All in the Twenty-First Century* adopted
1998	U.S. National Academy of Sciences recommends routine vitamin supplements for adults
1998	Bologna Declaration on post-graduate education in Europe adopts BA, MA, and PhD levels
1998	United States and Canada adopt mandatory fortification of flour with folic acid to prevent birth defects
1999	U.S. Congress passes legislation regulating patients' rights in managed care
1999	Master Settlement Agreement between U.S. states and tobacco companies for $206 billion for Medicaid damages
2001	9/11 Terrorism and mass casualties in United States
2001	Anthrax and bioterrorism
2003	SARS epidemic in China reaches Toronto; 8098 total cases with 774 deaths
2004	Tsunami and mass casualties in southeast Asia
2005	Hurricanes Katrina and Rita with widespread devastation and mass casualties
2006	Bird flu of H5N1 virus threatens world pandemic
2006	Human papillomavirus (HPV) vaccine approved by FDA for prevention of cervical cancer
2006	Medicare Part D prescription drug plan for seniors instituted in United States
2007	HPV vaccine in wide use for preteen girls in industrialized countries

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