CHAPTER

Public health and management 1

1.1 Introduction

Public health is a broad term applied to practice to strengthen health services for community well-being under which people can maintain good health, improve their health, or prevent the deterioration of their health. Public health covers the entire spectrum of health and well-being. Public health-care providers are mainly hospitals, physicians, community health centers, and nursing homes that provide preventive, curative, and rehabilitative care. Security professions, fire, ambulance providers, and emergency medical services are closely associated with public health providers.

Public health services function effectively with the collaborative efforts of multidisciplinary teams consisting of doctors, nurses, medical assistants, and many other. Public health management covers the administrative and managerial capacities, organizational structures, and systems needed to finance and deliver health services more efficiently, effectively, and equitably.

1.2 Definition

"Public health is the science governing with prevention of disease that is a threat to the overall status of health performance of a community, as well as with prolonging life and promoting health" [1]. The main functional aspect of public health is to put organized efforts for the well-being of the community with a healthy lifestyle. Delphi recommends facilitating technique to obtain anonymous acceptance of its suggestion for use in health research and public health development [2,3].

In 1997, Delphi study was able to develop a set of "essential public health functions" [4], which was at a later stage modified by the Pan America Health Organization and the World Health Organization (WHO) Regional Office for the West Pacific [5]. The Delphi method is a process used to arrive at a group opinion or decision by surveying a panel of experts.

For further adaptation, WHO Regional Office for Europe (WHO, EURO) has developed 10 Essential Public Health Operation (EPHO) [6].

1.3 The history of public health

In the beginning, the public health developers had to confront with some pessimistic people with vested interest, who used to discourage the public health services procedural follow-up by quoting some unusual social ethics. Opposition to Jennerian

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vaccination, unnecessary criticism of the work of great pioneers in public health measures such as Louis Pasteur, Florence Nightingale, and many others had unnecessarily delayed the innovative breakthrough in preventing diseases.

Jenner's vaccination is the most interesting factual story on public health services. The Egyptian mummies from the 18th and 20th Egyptian Dynasties (1570–1085 BC) having small lesions resembling those of smallpox was the first evidence of smallpox existing. But it is believed that smallpox first appeared around 10,000 BC, at the time of the first agriculture settlements in Northeastern Africa. European states were victimized sometime between the fifth and 6th centuries and later were brought to the New World by Spanish and Portuguese conquistadors, where it decimated the native populations. Smallpox is mainly caused by exposure to the *Variola* virus and infection typically begins like a common cold.

Although opposition to Jenner's vaccination continued till the late 19th century in some areas, its supporters gradually gained ascendancy, ultimately leading to the global eradication of smallpox.

In 1861, Louis Pasteur published germ theory which proved that bacteria caused diseases. This idea was taken up by Robert Koch in Germany, who began to isolate the specific bacteria that caused particular diseases, such as TB and cholera. Louis Pasteur's germ theory was discarded at the initial stage. People disapproved Louis Pasteur's model of infectious diseases and argued that Antoine Bechamp's theory was right [7]. Another observation was that the diseased tissues attract germs rather than being caused by them [8]. This was also a contradicted statement against germ theory developed by Louis Pasteur.

In 1881**,** Louis Pasteur developed a vaccine for anthrax, which was used successfully in sheep, goats, and cows. In 1885, while doing research on rabies, Pasteur tested his first human vaccine. This vaccine was developed by attenuating the virus in rabbits and subsequently harvesting it in their spinal cord. After his great success in developing, rabies vaccine for humans Pasteur was able to conclude that if a vaccine could be found for smallpox, vaccines could also be found for all diseases. In 1878, Pasteur successfully cultured the bacteria responsible for causing chicken cholera and began inoculating chickens (Fig. 1.1).

But during such a trial many chickens died. So, at a later phase, he emphasized on safe inoculation methods in order to avoid chicken death during inoculation. The incidental story on the chicken cholera vaccine was quite interesting. In 1879, Pasteur noticed that old bacterial cultures were lacking the virulence. Incidentally, Pasteur gave instructions to laboratory assistance to inoculate fresh culture of the viral bacteria before leaving for holiday. Unfortunately, the laboratory assistant forgot to inoculate the chicken with fresh bacterial culture. After returning from 1 month holiday, he performed the same job by inoculating old culture to the chicken and surprisingly could notice only mild signs of diseases and chickens survived. At a later phase when the chicken was healthy, Pasteur inoculated the healthy chicken with fresh bacterial inoculums and surprisingly noticed the chicken with good health.

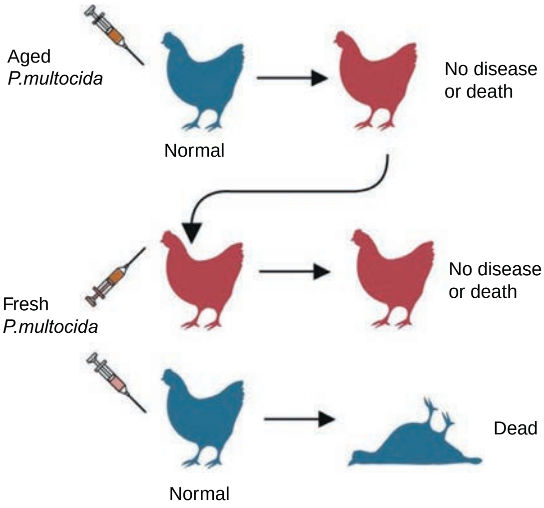


FIG. 1.1

Pasteur's fowl cholera experiment. Birds inoculated with an aged culture of *Pasteurella multocida* did not die. However, when subsequently inoculated with a fresh culture of virulent *P. multocida,* the birds were found to be protected. It was this experiment that launched the science of immunology.

Pasteur came to conclusion that by exposing to ambient atmospheric oxygen condition lost their virulence potential. The discovery of the chicken cholera vaccine by Louis Pasteur revolutionized work in infectious diseases and can be considered the birth of immunology.

The conceptual development of public health-care approaches can be well explained under the following heads.

1.3.1 Public health care and social ethics

Epidemics such as plague, cholera, and smallpox were dominated before the 18th century. Under the cloud of social ethics and inheritance of mythological believes people depend on God's blessing to prevent and cure diseases. People believed in a healthy deity (god or goddess) in mythology or religion associated with health, healing, and well-being, and also related to childbirth or mother goddesses (Fig. 1.2).

Epidemic diseases were used as signs of poor moral and spiritual conditions, to be governed through prayer and piety (Fig. 1.3). Some pandemic epidemic was monitored through isolation of ill and quarantine of travelers. In the late 17th century, several European cities appointed public authorities to adopt and enforce isolation and quarantine measures [9].

FIG. 1.2

People worship energy goddess for curing CORONA-19 (South China, India).

Hindu residents wearing protective masks perform prayers for protection against coronavirus outside a temple, in Ahmedabad, India [Amit Dave/Reuters]

Ahmed, 57 and his son, 10, perform Friday prayers in their home as mosques are closed due to concerns about the spread of coronavirus disease in Casablanca, Morocco [Youssef Boudlal/Reuters]

FIG. 1.3

Mass prayer for COVID-19 performed in different countries.

1.3.2 Restriction in public movement

The practice of isolation of ill, and quarantine of travelers before entering new countries were noticed to be a common measure for the prevention of pandemic contagious diseases. In 1701, Massachusetts passed the law for quarantine for traders and isolation of sick suffering from smallpox. By the end of 18th century, several cities like Boston, Philadelphia, New York, and Baltimore had well-framed quarantine and isolation rules as prevention measures against pandemic diseases [10].

During this period most of the developed cities established voluntary general hospitals for the physically ill and public institutions for the care of the mentally ill. Even the government made an official rule to take care of the physically and mentally ill by the neighbors in local communities [11,12].

By the end of the 18th century, several communities started demanding better formal arrangements for the care of their ill than Poor Law practices. The first American voluntary hospital was established in 1752 and in New York in 1771. The first public mental hospital was established in Williamsburg, Virginia in 1773 [13].

1.3.3 Sanitization awareness and public health care

Public awareness on sanitization intensified at the beginning of 19th century as an indicator of poor social and environmental conditions, and as well as for social and spiritual conditions.

In the 19th century, during the Victorian Era, the health and sanitization conditions were not to the mark. Tuberculosis, smallpox, measles-like bacteria/virus contamination in London was common. This was mainly due to horse transportation and cesspools filled the street with feces, and virus contamination was unavoidable (Fig. 1.4).

In the 19th century, horses were walking all day on the street, making the street road dirty and unhygienic with feces. The government employed young boys to clean the street road covered with feces from horses. But no improvement was noticed and

FIG. 1.4

London roads were dumped with horse's wastes (during 1800s). Near Regent street used to have 1000 horses for transport system.

FIG. 1.5

Georgian Era Toilets (Toilets in victorian-era.org).

the London Street was extremely unhygienic with horse feces. In Victorian era, every home used to have a cesspool (Fig. 1.5).

The only known place with toilets was called the Crystal Palace. Basically, cesspool was just deep holes that people would go to the bathroom in. Over time, the cesspool would fill up, and night workers would go around and empty them. It was illegal to empty the cesspool in the daytime due to an extremely foul smell. Some villagers would dump buckets of feces onto the sidewalk in the middle of the day which was another huge sanitary issue. In 1750, the population of Europe increased rapidly, with the simultaneous increase in infant death growth rate. These unfortunate incidents led to the rapid development of voluntary hospitals in the United Kingdom. The people's efforts had drawn the attention of the government to initiate precaution measures and extend public health facilities. In 1752, British physician Sir Johan Pringle published a book that explained ventilation in barracks and the provision of latrines.

In a developing country like India, sanitization has been a priority since ancient time, as scripted in Vedic times. The remnants of Indus Valley showed the awareness of people for public hygiene (Fig. 1.6).

But with the onset of the colonial role, sanitization ceased to be a national priority. The gradual increase in rural poverty under the colonial role has brought tremendous declination in rural hygiene conditions and ill health issues. During colonial rule, sanitization was given the least priority. In 1865, British Royal Commission reported a high mortality rate of 69 out of 1000 troops due to diarrhea. As a result, in

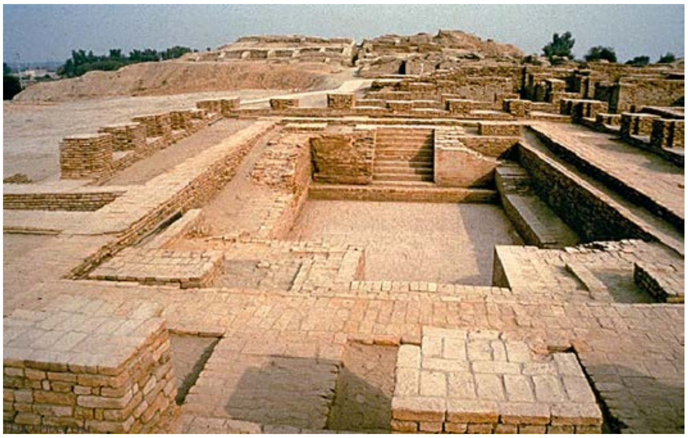


FIG. 1.6

The Harappan Bathroom (Harappa harappa.com).

1865, sanitization police were established under the Military Cantonments Act, and for the first time, sanitization boards were created in each province to look after civil sanitization conditions. This act was restricted to military areas rather than for the public. By 1947, India population was about 30 cores, had less than 1% sanitization coverage, and this statistical data prolonged for a long period.

Sanitization future prospects

The intensity of the COVID-19 pandemic has brought complete awareness among the people on personal hygiene. Things like regular and time-to-time hand washing (Fig. 1.7), use of face masks, maintaining a distance of 5 ft. seems to be casual, but

FIG. 1.7

Showing demonstration of hand washing as preventive measure for COVID-19.

are immensely important from a prevention point of view of contamination of infectious diseases like COVID-19.

Fabric masks are recommended to prevent onward transmission in the general population in public areas, particularly where distancing is not possible, and in areas of community transmission. So, masks are the physical barrier to respiratory droplets that may enter through the nose and mouth. The porosity of the fabric used for a mask is mainly dependent on the size of the pathogenic bacteria or virus (Fig. 1.8).

Nasal droplets and aerosols are more or less similar in size, less than 5 μm and can be transmitted over distances 1–2 m. The literature says "droplets" can be deposited as far away as 6–8 m. In the hospital environment, high infection rates were registered for several "aerosol-generating procedures" (invasive and noninvasive ventilation, intubation, tracheostomy, etc.); again, it has not yet been proved that aerosols are the culprits for the increased transmissibility but health-care workers are advised to wear N95/FFP2 or FFP3 in such a context. Currently, different types of face masks are available in the market to protect oneself from COVID19. The basic feature of the mask is as follows (Fig. 1.9A and B).

Mask provides against contaminants in the air, ranging from pollen to chemical fumes to pathogen. The quality of the mask depends on the nature of the fabric and design of the masks. Both disinfectants and sanitizers are used for controlling the infection. By means of sanitization, about 99.9% of surface pathogens are killed, whereas disinfections completely kill the pathogens. Disinfectants are made from quaternary ammonium compounds (quats), chlorine, (sodium hypochlorite, bleach), accelerated hydrogen peroxide or phenolic sanitizers. Sanitizers are chlorine, quats, iodine, and acid anionic. It is assumed that the use of hand sanitizers would become as normal in 2021 as sipping tea very often during winter.

On the 11th of February, WHO declared the name of the new diseases from the virus of Coronaviridae family in the Nidovirales order known as "COVID-19." The name of this virus is derived from Latin corona means crown-like structure on the outer side of the virus [14].

There are mainly three ways of contamination of coronaviruses, including COVID-19. These are the direct route, indirect contact, and airborne transmission.

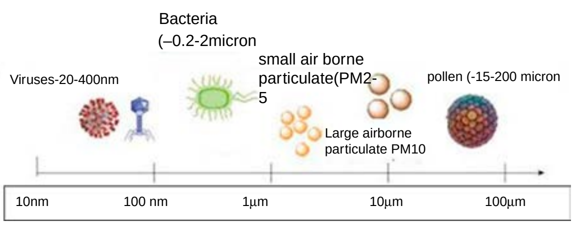


FIG. 1.8

Various size of bacteria and viruses.

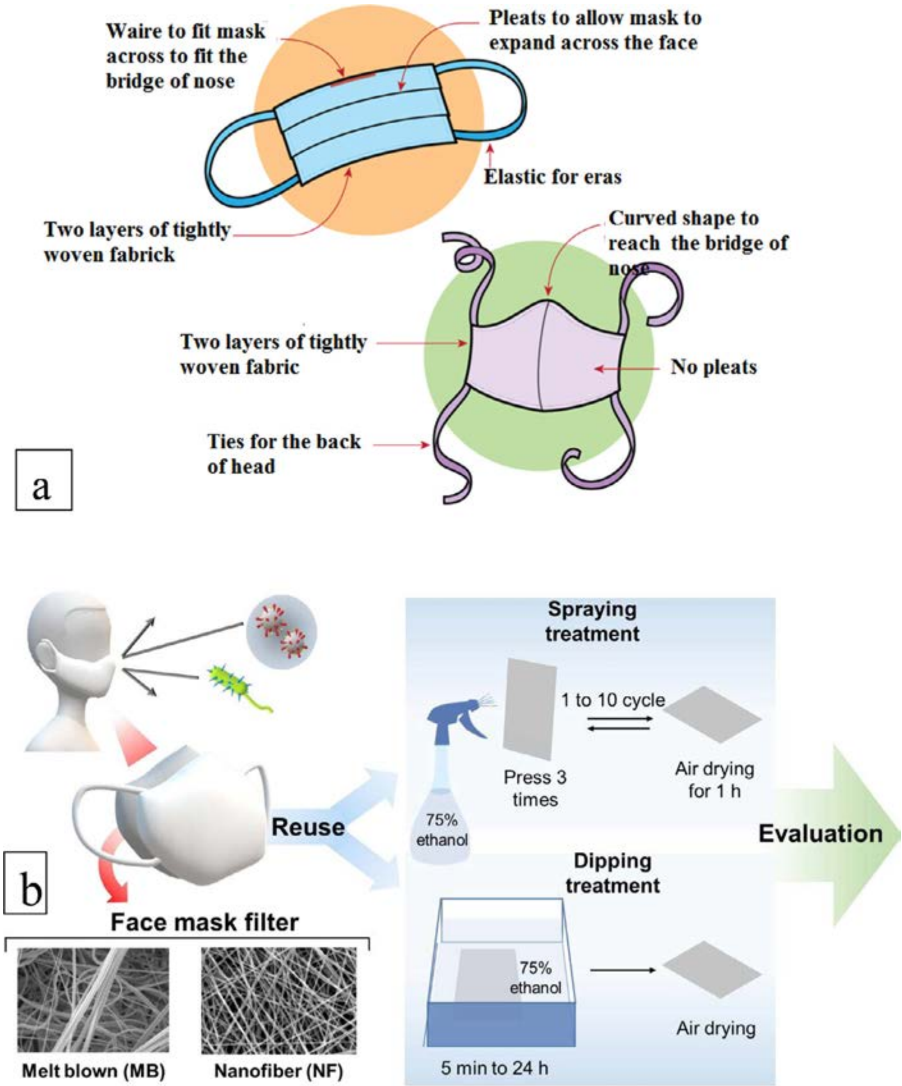


FIG. 1.9

Basic feature of mask (A) mask made from normal fabric, (B) mask made from nanopore material.

The epidemic (COVID-19) is transmitted from human to human by multiple means, namely by droplets, aerosols, and fomites (Fig. 1.10).

The direct mode of transmission is from an infected individual to a healthy person by close contact without any prevention measures like using the mask. While the indirect mode of transmission of the virus is due to touching or using objectives earlier used or touched by an infected person [15].

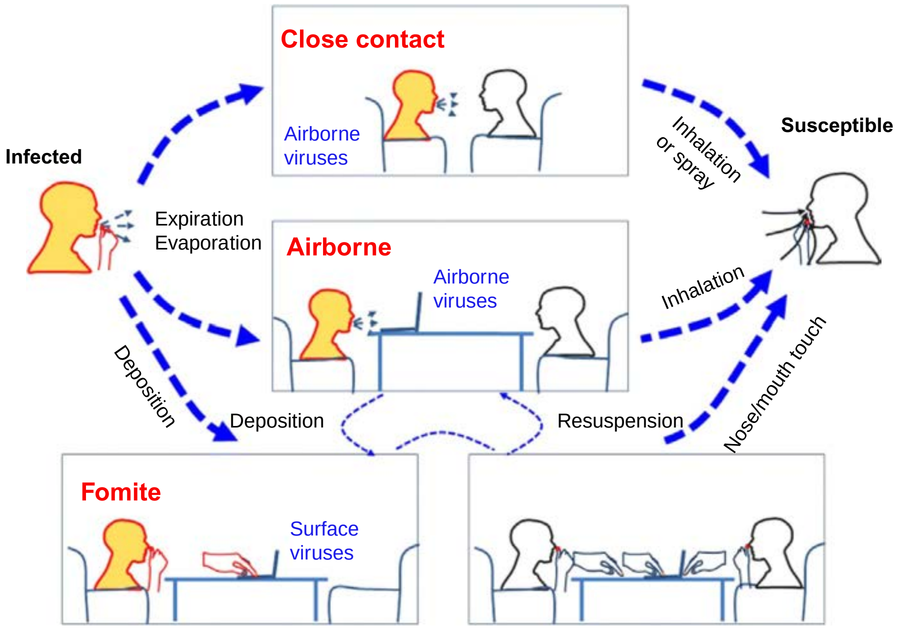


FIG. 1.10

Three ways of transmission of COVID-19 from contagious person to a healthy person.

1.3.4 Preventive measures

The end of 19th century was remarkable for rapid advances in scientific knowledge about the causes and prevention of numerous diseases caused by various pathogens. As stated earlier, in 1884, the concept of artificial immunization was developed by Louis Pasteur. During the following few years, the discovery of bacteriologic agents of diseases was made in European and American laboratories for coetaneous diseases such as tuberculosis, diphtheria, typhoid, and yellow fever [16].

During the same period lot of scientific data were available on the identification of bacteria and water purification techniques provided a means of controlling the spread of diseases and even preventing diseases. The basic concept of germ theory brought awareness about communicable diseases among the public and make the public understand that disease is mainly based on a single, specific cause. Scientists also revealed that both environment and people are sources of diseases. So, during this period, public agencies were more alerted to realize the significance of sanitization to avoid the contamination of diseases.

Identification of pathogens and interference of immunization and water purification techniques were used to control and prevent diseases. Scientists were immensely involved in research to understand the exact cause of disease and developed measures for controlling the disease.

For the first time, in 1890, the state and local health departments in the United States began to establish laboratories. The first was established in Massachusetts, as a cooperative venture between the State Board of Health and the Massachusetts Institute of Technology. In New York City, it was developed as a part of the New York City Health Department.

In 1891, W.T. Sedgwick, the most famous worker in sanitation and bacteriologic research, and consulting biologist for Massachusetts was able to identify the presence of fecal bacteria in water as the cause of typhoid fever and developed the first sewage treatment techniques. In 1890, Sedgwick conducted research on bacteria in milk and explained the benefit of pasteurization of milk.

In 1884–86, Theo Bald Smith, an American microbiologist, discovered the causes of several infectious and parasitic diseases. He found out that animals can be made immune to a disease by the injection of heat-killed cultures of the bacterium responsible for a specific disease. He was able to point out that the actual cause of hog cholera is a virus rather than *S. choleraesuis*, and developed techniques on the preparation of vaccine by a heat-killed method by disease-causing microorganisms. In 1888–93, Smith discovered Texas cattle fever caused by a protozoan parasite (*Pyrosoma bigeminum*, later named as *Babesia bigemina*) that is uninfected cattle by blood-sucking ticks.

1.3.5 The move toward personal care

In the early 20th century, both the local public and state government health departments became more conscious about public health. Identification and treatment of individual cases of diseases became the first priority. Massachusetts, Michigan, and New York City began producing and dispensing antitoxins in the 1890s. In 1907, Massachusetts Started reporting individual cases of 16 different diseases. At a later stage, cases of cancer also added in registering diseases.

Based on the data survey, it was realized that providing immunizations and treating diseases did not solve all health problems. Numerous diseases, such as tuberculosis, still remain unsolved despite sincere efforts. During World War I, it was understood that a substantial portion of the male population was either physically or mentally unfit for combat [17].

Overall results from registration also clear highest rates of morbidity persisting among children and poor. So, in order to have control over child mortality, the New York and Baltimore health departments started home visits by public nurses. To bring awareness among the people, New York health-care centers started a campaign on education on tuberculosis. In 1894, school health clinics were developed in Boston, New York. Subsequently, many cities like New York (1903), Rhode Island (1906) also developed child health-care centers. In 1915, more than 500 tuberculosis clinics and 538 baby clinics were developed in America [12].

Gradually, people have given to this movement a public health care for the prevention of diseases. Epidemiology provided a scientific justification for health programs that had originated with social reforms. Subsequently, in 20th century, scientists started research and development work on detailed analysis of diseases and treatment protocol. So, keeping in view such development, in 1923, C.E.A. Winslow defined public health as: “as Prolong life, and promoting physical health and efficiency” [10].

1.3.6 Toward improvement of public health

The late 19th century and early 20th century have witnessed federal involvement in public health development programs. In 1887, the National Hygiene Laboratory was established in the Marine Hospital in Staten Island, New York, in collaboration with chemistry, zoology, and pharmacology. In 1906, Congress passed the FOOD and Drug Act, for initiating manufacturing and, control, and sales of food and drugs. In 1912, the Marine Hospital Service was named the US Public Health Service. In 1914, Congress passed the Chamberlain-Kahn Act, to establish the US Interdepartmental Social Hygiene Board, a comprehensive venereal diseases control program for the military, and provided funds for quarantine of infected civilians. The Children’s Bureau (founded in 1912) conducted the first White House Conference on child health in 1919 [10].

In 1922, the Sheppard-Towner Act was established by the Federal Board of Maternity and Infant Hygiene in order to provide administrative funds to the Children’s Bureau to develop and conduct programs in maternal and child health. Through this act direct funding was provided for personal health services. The state government availed these funding facilities after the submission of a detailed report on the development plan and its proper implementation for improving or developing nursing facilities, home care, health education, and obstetric care mothers in the state; to designate a state agency to administer the program and to report on operations and expenditures of the program to the federal board [18].

Vaccines, which bridge the gap between biomedical science and public health, are one of the greatest achievements of the 20th century. Mass vaccination was the most important step taken as preventive measure for some deadly communicable diseases such as smallpox. Many methodological advances have facilitated a better understanding of diseases processes and opportunities for control.

Following are the few important developments in vaccination during 20th and 21st centuries (Table 1.1).

1.3.7 Finance involvement

Developed country like United States, spends more per capita health expenditure as compared to developing countries. Health spending per person in the United States was $ 10,966 in 2019, which was 42% higher than Switzerland, the country with the next higher per capita health spending (Fig. 1.11).

Table 1.1 Showing few important developments in vaccination during 20th and 21st centuries.

Year of development	Type of diseases	Name of scientist
1921	Tuberculosis	Albert Calmette
1923	Diphtheria	Gaston Ramon, Emil von Behring and Kitasato Shibasaburo
1924	Scarlet fever	George F, DICK AND Gladys Dick
1924	Tetanus (tetanus toxoid, TT)	French Gaston Ramon, C. Zoeller and P. Descombey
1926	Pertussis (whooping cough)	Leila Denmark
1932	Yellow fever	Max Theiler and Jean Laigret
1937	Typhus	Rudolf Weigl, Ludwik Fleck and Zinsser
1937	Influenza	Anatol Smorodintsev
1941	Tick-borne encephalitis	
1952	Polio (Salk vaccine)	
1954	Japanese encephalitis	
1954	Anthrax	
1957	adenovirus-4 and 7	
1962	Oral polio vaccine (Sabin vaccine)	
1963	Measles	
1967	Mumps	
1970	Rubella	
1977	Pneumonia (Streptococcus pneumonia)	
1978	Meningitis (Neisseria meningitides)	
1980	Smallpox declared eradicated worldwide due to vaccination efforts	
1981	Hepatitis B (first vaccine to target a cause of cancer)	
1984	Chicken pox	
1985	*Haemophilus influenzae* type b (HiB)	
1989	Q fever	
1990	Hantavirus hemorrhagic fever with renal syndrome	
1991	Hepatitis A	
1998	Lyme disease	
1998	Rotavirus	
21st century		
2003	Influenza vaccine approved in US (Flu Mist)	
2006	Human papillomavirus (which is case of cervical cancer)	

Continued

Table 1.1 Showing few important developments in vaccination during 20th and 21st centuries—cont'd

Year of development	Type of diseases	Name of scientist
2012	Hepatitis E	
2012	quadrivalent (4-strain) Influenza vaccine	
2015	Enterovirus 71, one cause of hand foot mouth disease	
2015	Malaria	
2015	Dengue fever	
2019	Ebola approved	
2020	COVID-19	

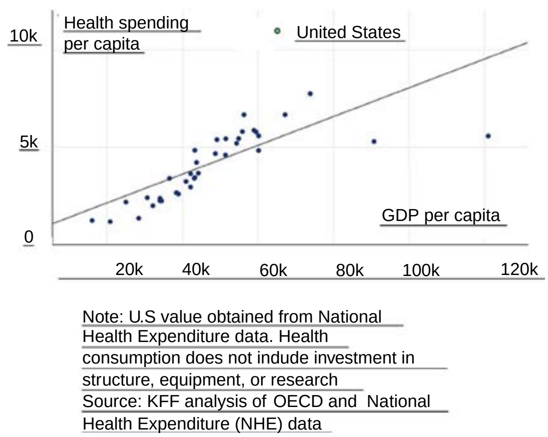


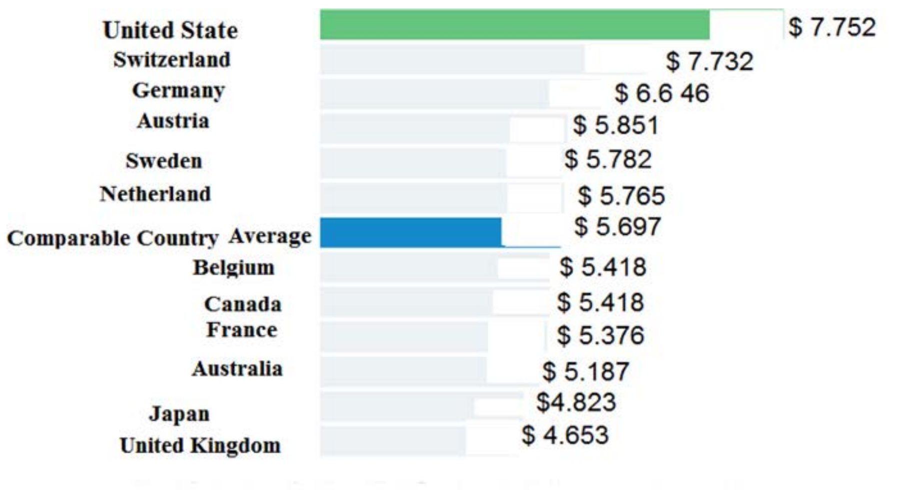
FIG. 1.11

GDP per capita and health consumption spending per capita, 2019 (US dollar, PPP adjusted).

On average, other wealthy countries spend about half as much per person on health than United States (Fig. 1.12).

China also ranks below the Organization for Economic Cooperation and Development (OECD) average in terms of health expenditure per capita, spending USD 480 in 2012, compared with an OECD average of USD 3484 (Table 1.2).

India 2020 population is estimated at 1,380,004,385 people at the midyear according to UN data. India population is equivalent to 17.7% of the total world population. Overall, India's public health expenditure has remained between 1.2% and 1.6% of GDP between 2008 and 09 and 2019–20.



Note: U.S value obtained from National Health Expenditure data. Health consumption does not include investment in structure, equipment or research.. Source: KFF analysis of OECD and National Health Expenditure (NHE) data

FIG. 1.12

Showing health consumption expenditure per capita, US dollar PPP adjusted, 2019.

Table 1.2 Health expenditure per Chinese citizen from 2009 to 2019 (in Yuan) per capital health expenditure in yuan.

Year	Health expenditure (Yuan)
2019	4702.9
2018	4236.98
2017	3783.83
2016	3351.74
2015	290.8
2014	2582.60
2013	2327.37
2012	1806.95
2011	149.95
2010	1490.50
2009	1313.3

1.4 Types of health problems and diseases

Health problem refers to abnormal functioning of the health system due to some pathological infection or some other disorder without any pain. The synonyms of health problems may be ill health or unhealthiness. Overall condition of health can be categorized into four groups: (i) infectious diseases, (ii) deficiency diseases, (iii) hereditary diseases, and (iv) physiological diseases.

Diseases can also be classified as communicable versus noncommunicable diseases.

1.4.1 Diseases classification as per Britannica encyclopedia

As per Britannica Encyclopedia, diseases are classified as (Fig. 1.13): (1) topographic, by bodily region or system, (2) anatomic, by organ or tissue, (3) physiological, by function or effect, (4) pathological, by the nature of the disease process, (5) etiologic (causal), (6) juristic, by the speed of advent of death, (7) epidemiological, and (8) statistical. Any single disease may fall within several of these classifications.

(i) Topographic Classification

Under this category, diseases are subdivided into gastrointestinal diseases, vascular diseases, abnormal diseases, and chest diseases. Generally, doctors specialized in

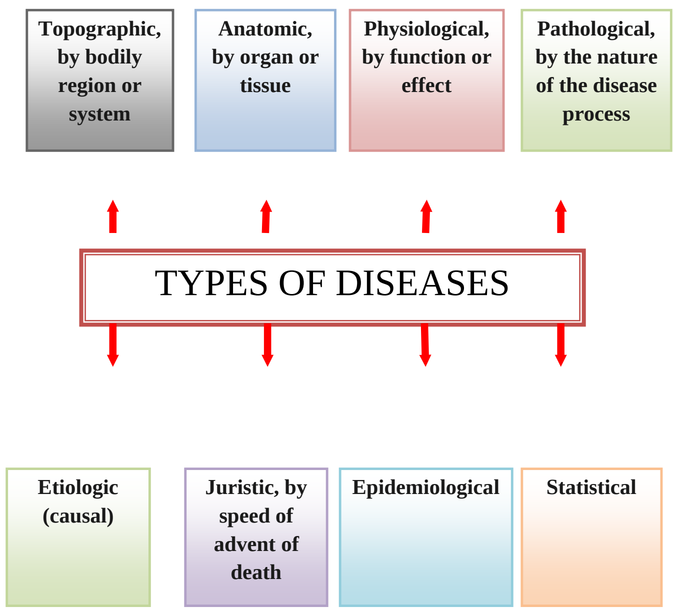


FIG. 1.13

Types of diseases as classified by Britannica Encyclopedia.

medicine, gastrointestinal diseases, chest diseases follow such topographic or systemic divisions.

(ii) Anatomical classification

This classification is mainly based on organs or tissue affected by diseases such as heart diseases, lung diseases, and liver diseases. Cardiologists, urologists, neurologists belong to this category. Even atherosclerosis of the coronary arteries come under this category of disease.

(iii) Physiological classification

This classification is mainly based on the functional disorder of any organs produced by a specific disorder. Examples include respiratory or metabolic diseases. Respiratory diseases are mainly involved in the interference of intake and expulsion of oxygen and carbon dioxide. Diabetes and gout problems are also under this category.

(iv) Pathological classification

The pathological classification is based on the effect of foreign bodies on the normal structure and function of the body as a whole or part. Neoplastic and inflammatory diseases are examples. Neoplastic disease includes the whole range of tumors, particularly cancers, and their effect on human beings.

(v) Etiologic classification of diseases

Etiology (from Greek word meaning the study of cause) in medicine is known as the determination of a cause of diseases or pathology. One disease entity can have more than one etiology that can lead to more than one disease. The etiology is mainly caused by biological interference. On this basis, diseases might be classified as an example, staphylococcal or rickettsial or fungal origin.

Etiology focuses on the back story of a disease. The illness caused by etiology can be due to intrinsic (coming from within), extrinsic (originating from external factors), or idiopathic (cause unknown). Etiology is not only disease specific but also person specific.

(vi) Juristic basis

The juristic basis of the classification of diseases is concerned with the legal circumstances in which sudden death occurs in which the cause of death is not known.

(vii) Epidemiological classification

Epidemiology is a Greek origin word: *epi*, meaning on or upon, *dermos*, meaning people, and *logos*, meaning the study of "*Epidemiology is the study of the distribution and determinant of health-related states or events in Specific population, and the application of this study to the control of health problem*" [19].

Originally, epidemiology focused exclusively on epidemics of communicable diseases [2] but was subsequently expanded to address endemic communicable diseases and noncommunicable diseases.

(viii) Statistical disease classification

The statistical basis of classification of disease is mainly based on analysis of the incidence of a particular disease and occurrence rate after a specific time period. For example, if a disease occurrence is 100 in number, and a period of 3 years, the prevalence would be 300. By statistical analysis, it would be possible to understand the possible cause of disease on the basis of cumulative data analysis related to food habits, or epidemiological, nutritional, and pathological analysis. The statistical analysis is on the high level of fats and carbohydrates may be the cause of atherosclerosis.

1.4.2 Diseases classification on contamination basis

Communicable diseases

Disease is an abnormal condition of health that may be due to interference of external factors such as (i) pathogens or (ii) internal dysfunctions. Infectious diseases are transmitted from a person by direct or indirect means. Some of the important contagious diseases include: COVID-19 (2019-nCoV in which "n" is for novel and "CoV is for coronavirus"), Norovirus (Stomach Flu), Influenza, Meningitis, pertussis, sexually transmitted diseases, methicillin-resistant *Staphylococcus aureus* (MRSA).

Decline in communicable diseases

As stated in WHO 2019 report, there was a remarkable decline in deadly diseases such as pneumonia and other lower respiratory infections which were the fourth leading cause of death in 2000. The global number of death due to such diseases has decreased by nearly half a million [19].

In 2019, globally, HIV/AIDS dropped from the 8th leading cause of death as compared with the death rate in 2000. This could have been possible due to the success of efforts to infection, test for the virus, and treatment of the diseases over the last two decades. About 6.2% of the world's population is contaminated with HIV. In 2018, there were 800,000 new HIV infections, worldwide [20].

East and Southern Africa is the region hardest hit by HIV. In 2018, South Africa accounted for more than a quarter (240,000). In addition, seven other countries accounted for more than 50% of new infections: Mozambique (150,000), Tanzania (72,000), Uganda (53,000), Zambia (48,000), Kenya (46,000), Malawi (38,000), and Zimbabwe (38,000) [20]. Overall, new infections in the region have declined by 28% since 2010 [21]. In this region, in 2018, the number of deaths has fallen by 44% since 2014 [21]. In 2018, 85% of people living with HIV were aware of their status, and 79% of them were on treatment (equivalent to 67% of all people living with HIV in the region) [22].

In 2019, the global death rate of tuberculosis was not in the top ten death rate, as compared to its 7th place in 2000. There was about a 30% reduction in global death. But, it still remains among 10 causes of deaths in the African and South-East Asian regions, where it is the eighth and fifth leading cause, respectively.

WHO reports also highlight that the total communicable diseases still persist in low-income countries. Six of the top 10 causes of death in low-income countries are still communicable diseases, including malaria (6th), tuberculosis (8th), and HIV/AIDS (9th). But, at the global level, the overall decrease in the death rate due to communicable diseases has gone down.

Current scenario in COVID-19

It was in December 2019, the first report on coronavirus-related pneumonia (SARS-Co-2) appeared in the public domain and created havoc. It was on January 11, 2020, the first death was recorded in Wuhan, China, and by this time global deaths were set to reach 2 million. Within a period of 4 months the death rate reached 1 million on September 28, 2020, to 2 million on January 15, 2021; people in over 210 countries were conformed with COVID-19 and 2 million people died.

List of top 10 communicable diseases

Following are the top 10 communicable diseases, as reported by WHO: 2019-n CoV, CRE, Ebola, Enterovirus D68, Flu, Hantavirus, Hepatitis A, Hepatitis B, HIV/AIDS, Measles, MRSA, Pertussis, Rabies, Sexually Transmitted Diseases, Shigellosis, Tuberculosis, West Nile Virus, and Zika.

Noncommunicable diseases

Mainly, noncommunicable diseases are responsible for the cause of more death as compared to communicable diseases. As reported by WHO [23], in 2019, the top 10 causes of death accounted for about 55% of the 55.4 million deaths worldwide. Mainly, the three broad groups of diseases associated with the 10 top global death are (i) cardiovascular (ischemic heart diseases, stroke), (ii) respiratory (chronic obstructive pulmonary disease, lower respiratory infections), and (iii) neonatal conditions which include birth asphyxia and birth trauma, neonatal sepsis and infection, and preterm birth complications.

The last two decades have been witnessing heart disease as the leading cause of death at the global level. The number of deaths from heart disease increased by more than 2 million since 2000, to about 9 million in 2019. Heart is reported as 16% of the total deaths from all causes. The WHO Western Pacific Region is intensely under the grief of noncommunicable diseases (NCDs) like cancer, diabetes, and chronic respiratory diseases. But European region has seen a relative decline in heart diseases, with death falling by 15% (www.who.int/countries for the list of countries in each WHO region).

Alzheimer's and other forms of dementia are on the list of the top 10 globally acclaimed NCDs. The death due to Alzheimer has occupied third in both the Americas and Europe in 2019. The female death rate due to this disease is about 65% as compared to the male death rate. Death due to diabetes has increased by 70% globally between 2000 and 2019. In the Eastern Mediterranean, deaths from diabetes have more than doubled and represent the greatest percentage increase of all WHO regions.

WHO presents the most comprehensive and update information on population health, including life expectancy, healthy life expectancy, mortality and morbidity, status of diseases, at the global level (Fig. 1.14). Information on these issues results

FIG. 1.14

Concept on population health management.

from data survey of WHO from the best available resources around the world. Robust health data are critical to have control and prevention of diseases at the family, community, and global level. In addition, a global health data bank is critical for analyzing the health impact on the economic status of a nation. As of today, COVID-19 has tragically claimed more than 1.5 million lives. People living with preexisting health conditions such as heart diseases, diabetes, and respiratory diseases are at higher risk of complications due to COVID-19.

1.4.3 The international classification of diseases

The International Classification of Diseases (ICD) is a global body maintained by the World Health Organization (WHO), directed and coordinated by the authority of health within the United Nations System. Presently, ICD is a globally used diagnostic tool for epidemiology, health management, and clinical purposes. The ICD is a core statistical-based diagnostic system for health-care-related issues of the WHO Family of International Classification (WHO-FIC).

Conceptual development of ICD

In 1860, during the international statistical congress, Florence Nightingale proposed a developing model on international health data analysis. Subsequently, in 1893, Jacques Bertillon, a French Scientist, at a congress held in Chicago, proposed a comprehensive model on causes of death entitled “Bertillon Classification of Causes of Death.” A number of countries adopted Dr. Bertillon’s system. In 1898, the American Public Health Association (APHA) recommended Canada, Mexico, and United States to also adopt. Besides this, APHA also recommended revising the system every 10 years in order to update with current development in this regard. In August

1900, for the first time, a conference on Revision of the Bertillon or International List of causes of death was held in Parish. Delegates from 26 countries participated in this conference. In August 1900, a detailed classification of causes of death with 179 groups, and a shorten classification of 35 groups were framed. In subsequent years, series of meetings starting from 1910 were held, with a gap of 10 years (Table 1. DDD). The French Government called succeeding conferences in 1920, 1929, and 1938 to revise the classification for health-related death for six times and resulted in the development of two volumes. The final getup of these two volumes contained mortality and mortality conditions with the title "Manual of International Statistical Classification of Diseases, Injuries and Causes of Death (ICD)."

The six revisions were related to morbidity and mortality conditions, and the title was changed, accordingly: "Manual of International statistical classification of Diseases, Injuries and Causes of Death (ICD)." In 1948, the WHO had taken responsibility for developing and publishing revisions to the ICD. At a later stage, WHO had also taken the responsibility of revising and publishing seventh and eighth in 1957 and 1968, respectively. Subsequently, the ninth revision of the ICD (ICD-9) was published in 1978. Later on, the US Public Health Service made a modification in ICD-9 in order to meet the needs of American hospitals and called it International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

In May 1990, the 43 World Health Assembly recommended ICD-10. It is cited in more than 20,000 scientific articles and used by more than 150 countries around the world. It was translated into more than 40 languages.

The ICD-10 consists of

- Detail tabular list containing cause-of-death, and code number (Volume 1)
- Inclusion and exclusion terms for cause-of-death title (Volume 1)
- An alphabetical index to diseases and nature of the injury, external causes of injury, table of drugs and chemicals (Volume 3)
- Description, guidelines, and coding rules (Volume 2).

The conversion of ICD-9 into ICD-10 has changed the presentation of mortality data systems which affect the instruction manuals, medical software, and analysis.

ICD-11 update

ICD-11 has been adopted by the 72 World Health Assemblies in May 2019 and will come into effect on January 1, 2022. ICD-11 introduced two striking features: extensions and clustering which would be helpful in post-cording and the addition of specific detail to coded entities. Both features have the potential to improve ICD-11 code data. The ICD-11 catalog is most important to specify human diseases, medical conditions, and mental health disorders and is used for insurance coding purposes, for statistical tracking of illnesses, and as a global health categorization tool that can be used across countries and in different languages.

The WHO keeps update responsibility in modifying or further developing ICD-11, on a need basis. It is due to the involvement of 300 specialists from 55 countries divided into 30 work groups.

Who can use ICD-11

Mostly, doctors, nurses, research scientists, health professors, workers involved in health-care management and technology, policy makers, and health insurance companies use ICD-11. All Member States use ICD. Presently, ICD is available in 43 languages. It is also applicable to systematically present mortality data as a primary indicator of health status. All Member States are entitled to use the most updated information on ICD from the public domain.

Important of ICD-11

The most significant achievement of ICD is its availability in different languages in order to attract global attention. This is immensely helpful having a comparative data structure for sharing, at a global level. ICD is the most reliable and evidence-based data bank in making a critical decision. The revision of ICD-11 for time and again is immensely helpful to keep updated progress in health sciences and medical practice. Through the application of the latest electronic communication, ICD-11 can be applicable in more efficient ways with minimum time. ICD-11 also works well for collaborative web-based editing that is open to all interested parties.

1.5 Outbreaks, epidemic, and pandemics

In epidemiology terminology, a sudden increase in the occurrence of a specific disease for a particular time and place is known as an outbreak. Outbreaks include epidemic, which has restricted use for infectious diseases or environmentally origin diseases like water or foodborne disease which may affect a locality in a country or a group of countries. Pandemics are near-global disease outbreaks when multiple countries across the world are infected (Fig. 1.15).

1.5.1 Outbreaks

As stated above, outbreaks may last for few days or linger for months or several years (Fig. 1.16). Some outbreaks are supposed to be yearly basis such as influenza. Sometimes a single case of an infectious disease may be considered outbreak (e.g., food-borne botulism or bioterrorism agent such as anthrax).

On February 12, an outbreak of the Ebola virus in the Democratic Republic of the Congo was a great concern for Public health emergency of international concern (PHEIC). The Committee acknowledged the outbreaks as high at a national and regional level and low at the global level.

Causes of diseases outbreaks

Generally, the most common causes of disease outbreaks include infection, transmission through person-to-person contact, animal-to-personal contact, or from the environment or other media. Expose to chemical or radioactive materials may also cause outbreaks of disease. Communicable diseases can also be transferred

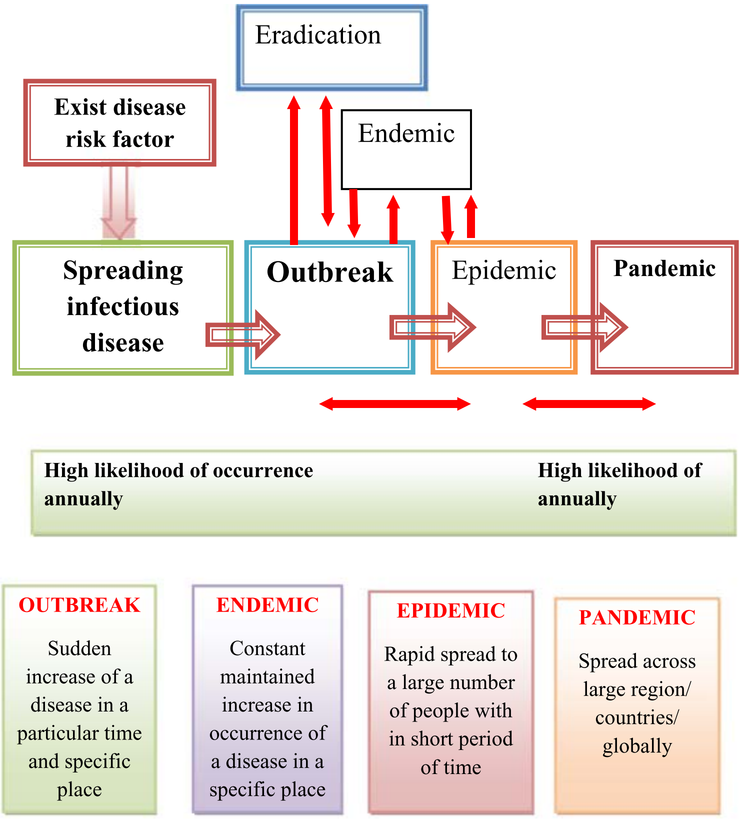


FIG. 1.15

Pandemic and spread infection disease.

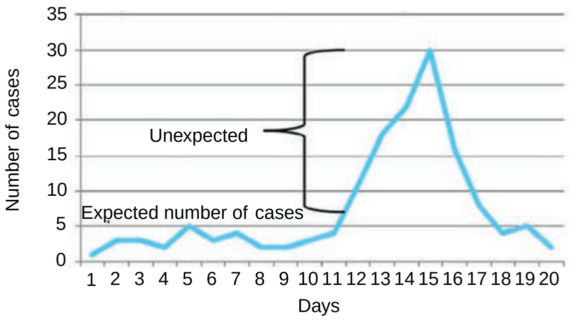


FIG. 1.16

Showing outbreak of a disease in which occurrence of more cases of a disease than expected for a particular place and time prior to taking any preventive measures.

Source: Centre for Disease Control and Prevention (CDCP), United State. Disease clusters: an overview case definition from the United States Department of Health and Human Services http://www.atsdr.cdc.gov/HEC/CSEM/cluster/case_def.html.

through water, sanitation, and food and air quality. Poor hygiene, poor living conditions, mismanagement in waste disposal facilities, can also cause diarrheal diseases. These diseases are a major cause of suffering and death in an emergency situation.

1.5.2 Epidemic

Epidemic is referred to as the process of rapid spreading of an infectious disease to a large number of people in a given population within a short period of time. The Centers for Disease Control and Prevention (CDCP) defines epidemic as: "an unexpected increase in the number of disease cases in a specific geographical area." So, an epidemic is any rise in cases beyond the baseline for that geographic area.

In 2003, the severe acute respiratory syndrome (SARS) epidemic took the lives of nearly 800 people worldwide. The Plague of Athens was an epidemic that devastated the city-state of Athens in ancient Greece during the second year of the Peloponnesian War. The plague killed an estimated 75,000 to 100,000 people, around one-quarter of the population, and is believed to have entered Athens through Piraeus, the city's port and sole source of food and supplies.

On March 23, 2014, WHO declared the outbreak of Ebola Virus Disease (EVD) in the forest rural region of Southeastern Guinea. By July 2014, the outbreak spread to the capital of all three countries. A total of 28,616 cases of EVD and 11,310 deaths were reported in Guinea, Liberia, and Sierra Leone. This was the first time EVD extended out from more isolated, rural areas and into densely populated urban centers.

There are four types of influenza viruses: A, B, C, and D. Human influenza A and B viruses cause seasonal epidemics of disease almost every winter in the United States. Influenza A viruses are the only influenza viruses known to cause flu pandemics, i.e., a global epidemic of flu disease.

Based on the combination of surface proteins hemagglutinin (HA) and the neuraminidase (NA), influenza A is classified into subtypes: A(H1N1) and A (H3N2) influenza viruses. The A1(H1N1) is also written as A(H1N1)pdm09 as it caused the pandemic in 2009. Only influenza type A viruses are known to have caused the pandemic. But Influenza B viruses are without any subtypes. Influenza C virus is rarely seen and has also no important in public health. Influenza D is restricted to cattle and not infectious to humans.

Symptoms

Sudden onset of fever, dry cough, headache, muscle, and joint pain, severe malaise (feeling unwell), sore throat, and runny nose are some of the important symptoms of seasonal influenza. Illnesses range from mild to severe and even death. Generally, people from high-risk groups are hospitalized or die. Worldwide, these annual epidemics are estimated to result in about 3–5 million cases of severe illness, and about 290,000–650,000 respiratory deaths. In industrialized countries most deaths associated with influenza occur among people age 65 or older [24,25].

Causes of epidemic

Generally, epidemics of infectious diseases are caused by various factors like change in the ecology of the host population, a genetic change in the pathogen reservoir, or the introduction of an emerging pathogen to a host population. Due to sudden reduction in immunity potential of the host population caused by a new pathogen or genetically mutated pathogen may be responsible for epidemic outbreaks in a particular locality.

Infected food supplies such as contaminated drinking water and the migration of populations of certain animals, such as rats or mosquitoes (disease vectors) are also cause of the epidemic.

Generally, the epidemic outbreak is seasonal. Due to seasonal change, the physiology of the body and its immune system gets change. In temperature climates, a seasonal epidemic occurs mainly during winter, while in tropical regions, influenza may occur throughout the year, causing outbreaks more irregularly. The time from infection to illness, known as the incubation period, is about 2 days but ranges from 1 to 4 days.

Smallpox, cholera, yellow fever, typhoid, measles, and polio are some of the worst epidemics in American history.

Types of epidemics

Based on propagation, an epidemic can be classified into three groups: (i) common-source outbreaks, (ii) transmission (propagated or progressive epidemic), and (iii) mixed epidemics.

(i) Common-source outbreaks

Common-source epidemics are mainly due to exposure to an infectious agent, and occur frequently but not always. They are generated from the contaminated environment (air, water, food, soil) by industrial pollutants. For example, the Bhopal gas tragedy in India and Minamata disease in Japan resulting from the consumption of fish containing a high concentration of methyl mercury.

(a) *Single exposure or "point-source" epidemic*

If the exposure is singular, and all of the affected individuals develop the diseases over a single exposure, it can be termed a "point-source outbreak" (epidemic). Point-source outbreaks tend to have an epidemic curve with a rapid increase in cases followed by a somewhat slower decline, and all of the cases tend to fall within one incubation period. The graph below from a hepatitis outbreak is an example of a point-source epidemic (Fig. 1.17).

The incubation period for hepatitis ranges from 15 to 50 days, with an average of about 28–30 days. In point-source epidemic of Hepatitis, the rise and fall of new cases occur within about 30 days span of time.

The exposure to the disease agent is brief and essentially simultaneous; the resultant cases all develop within one incubation period of the disease (an epidemic of food poising). In a "point-source" the epidemic curve rises and falls rapidly without any secondary waves. In addition, the epidemic tends to be explosive, there is cluster of cases within a narrow interval of time, more importantly, all the cases develop within one incubation period of the diseases.

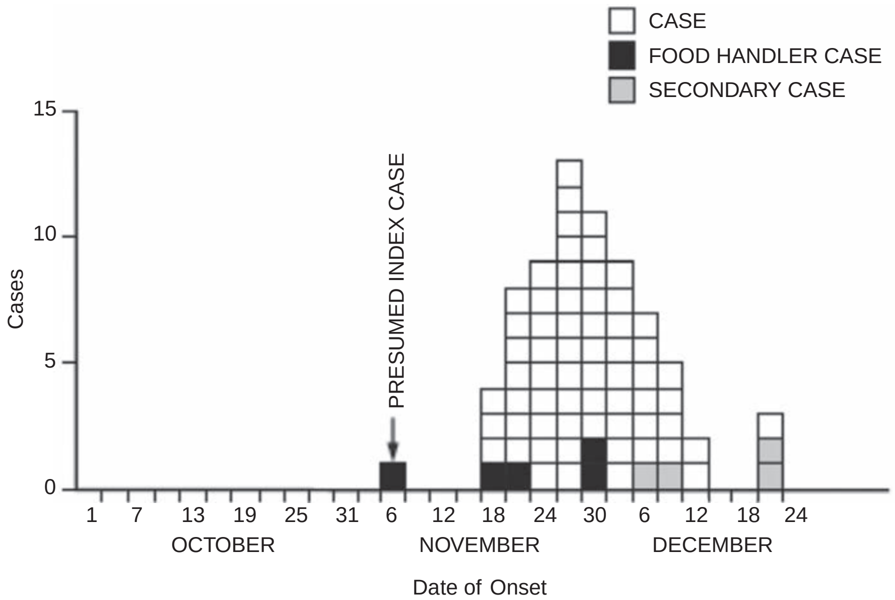


FIG. 1.17

Showing mode of spreading epidemic "point source."

(b) *Continuous or multiple exposure epidemics*

If the exposure is continuous or variable, it can be termed a continuous outbreak or intermittent outbreak, respectively (Fig. 1.18).

Sometimes the exposure from the same source may be prolonged, and continuous, repeated, or intermittent. For example, a prostitute may be a common source in a gonorrhea outbreak, but since she infects her client over a period of time, there may be no explosive rise in the number of cases. A single source of contaminated water, or a nationally distributed brand of vaccine (polio vaccine), or food may be responsible for similar outbreaks.

The spreading of disease from person to person is known as a propagated outbreak. Affected individuals act as independent reservoirs, as with syphilis. Transmission may also be vehicle borne (e.g., transmission of hepatitis B or HIV by sharing needles) or vector borne (e.g., transmission of yellow fever by mosquitoes).

If the exposure is singular, and all of the affected individuals develop the diseases over a single exposure, it can be termed a point-source outbreak. If the exposure is continuous or variable, it can be termed a continuous outbreak or intermittent outbreak, respectively.

(ii) Transmission (propagated or progressive epidemic)

Transmission is a process of propagation of disease from person to person, directly or indirectly (Fig. 1.19). Direct contact transmission occurs when there is

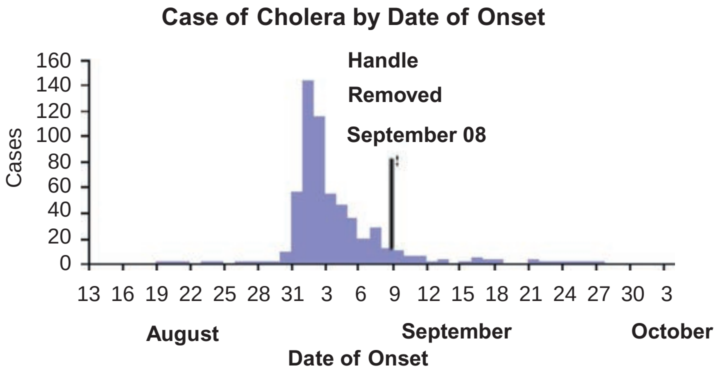


FIG. 1.18

The epidemic curve shows the cholera outbreak in the Broad Street area of London in 1854. Cholera has an incubation period of 1–3 days, and even though residents began to flee when the outbreak erupted, which can be seen that this outbreak lasted for more than a single incubation period.

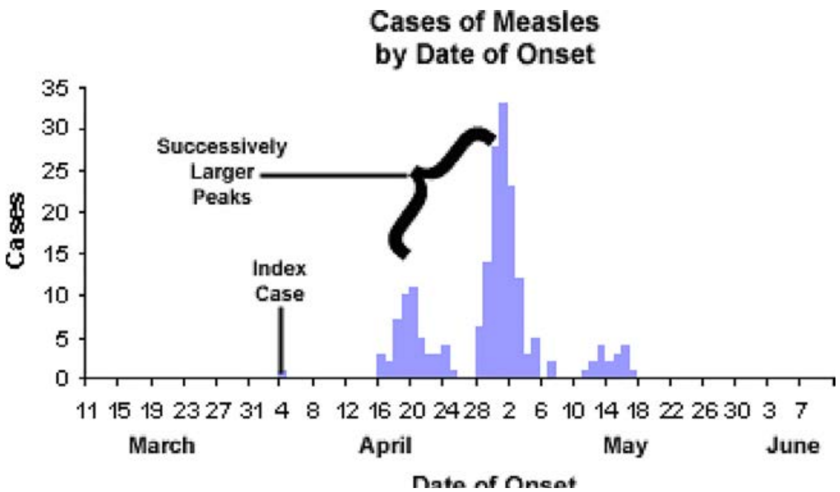


FIG. 1.19

Showing the epidemic curve from an outbreak of measles that began with a single index case who infected a number of other individuals. (The incubation period for measles averages 10 days with a range of 7–18 days).

physical contact between an infected person and a susceptible person. Indirect contact transmission occurs when there is no direct human-to-human contact. Contact occurs from a reservoir to contaminated surfaces or objectives, or to vectors such as mosquitoes, flies, mites, fleas, ticks, rodents, or dogs.

(a) *Spreading of infection*

Direct contact infections spread when pathogens pass from the infected person to the healthy person via direct physical contact with blood or body fluids. Examples of direct contact are touching, kissing, sexual contact, contact with oral secretions, or contact with body lesions. Indirect contact infections spread when an infected person sneezes or coughs, sending infectious droplets into the air. Droplets generally travel between 3 and 6 ft and land on nearby surfaces or objects including tables, doorknobs with their hands, and then touch their eyes, nose, or mouth.

A lot of diseases spread through contact transmission. Examples are chicken pox, common cold, conjunctive (pink eyes), hepatitis A and B, herpes, adeno/rhinovirus, neisserial, meningitides, and mycoplasma pneumonia.

(b) *The means of transmission*

Contact (direct and/or indirect), droplet, airborne, vector, and common vehicle are some of the important means of disease transmission processes. The portal of entry is the means by which the pathogens gain access to the new host. This can occur, for example, through ingestion, breathing, or skin puncture (Fig. 1.20A and B).

1.5.2.1 How to avoid

Earlier (Section 1.2.3), it has already been mentioned how frequent hand washing, use of mouth mask while out of the home. It is also recommended for regular disinfection of frequently touched surfaces such as doorknobs, handles, handrails, phones, office supplies, and children's toys. Using barriers such as gloves, masks, or condoms can help avoid the spread of germs.

(iii) Mixed epidemic

A mixed epidemic includes both common-source and propagated outbreak characteristics. For example, people infected through a common-source outbreak might later transmit or spread the disease through direct contact with others. Mixed epidemics are often caused by food-borne infectious agents.

1.5.3 Pandemic

A pandemic is an epidemic that spreads over multiple countries or continents. The world population have been confronting with a number of devastating pandemics diseases such as smallpox, tuberculosis, plague, etc. (Table 1.3).

Coronavirus

Coronaviruses belong to a large family of RNA viruses that have been around for a long time. Many of them can cause a variety of illnesses, from mild cough to severe respiratory illnesses. In humans and birds, they cause respiratory tract infections that can range from mild to lethal. Mild illnesses in humans show common cold with mild fever. The lethal variety of corona can cause SARS (Severe Acute Respiratory Syndrome), MERS (Middle East Respiratory Syndrome), and COVID-19.

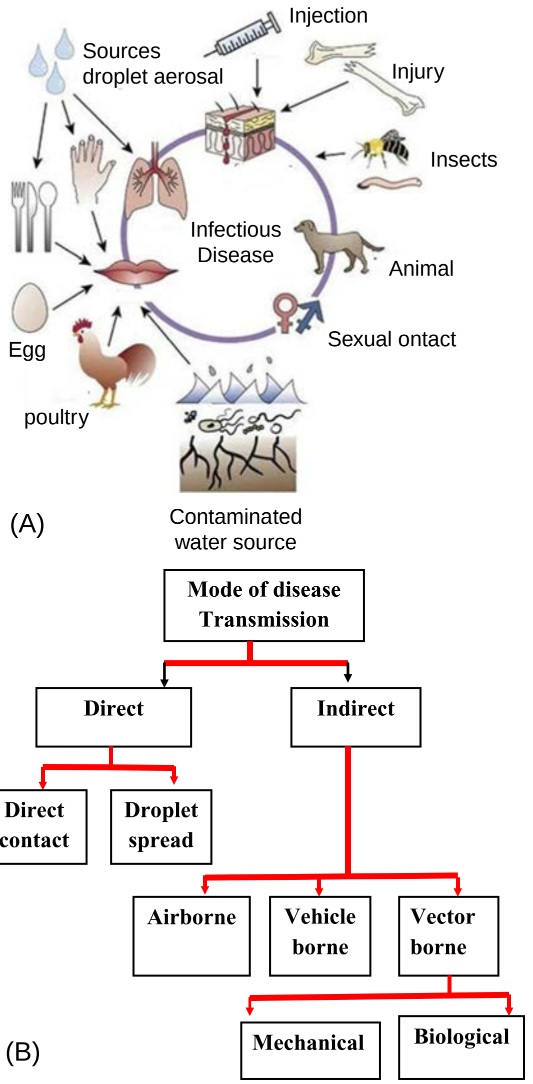


FIG. 1.20

(A, B) Showing mode of transmission of diseases.

The novel coronavirus causing COVID-19 is the one known to infect humans severely. Earlier, it is probably been around for some time in animals, and in due time crossed over into people. So, this virus is not new to the world, but it is new to humans. In 2019, it was known as novel coronavirus (n COV), which was subsequently named the “COVID-19” (“CO” stand for corona, “VI” for virus, and “D” for diseases) or SARS-CoV-2.

Table 1.3 Major epidemics and pandemics death tool.

Rank	Epidemics/pandemics	Death toll	Location
1	Black death 1346–1353	75–200 million	Europe, Asia, and North Africa
2	Spanish flu 1918–1920	17–100 million	Worldwide
3	Plague of Justinian 541–549	15–100 million	Europe and West Asia
4	HIV/AIDS pandemic 1981–present	35 million + (as of 2020)	Worldwide
5	Third plague pandemic 1855–1960	12–15 million	Worldwide
6	Cocoliztli epidemic 1545–1548	5–15 million	Mexico
7	Antonine plague 164–180	5–10 million	Roman Empire
8	Mexico smallpox epidemic 1519–1520	5–8 million	Mexico
9	COVID-19 pandemic 2019–present	2.93 million + (as of April 2021)	Worldwide
10	Russia typhus epidemic 1918–1922	2–3 million	Russia
11	Influenza pandemic 1957–1958	1–4 million	Worldwide
	Hong-Kong flu 1968–1969	1–4 million	Worldwide
13	Cocoliztli epidemic 1576–1580	2–2.5 million	Mexico
14	Japanese smallpox epidemic 735–737	2 million	Japan
	Persian plague 1772–1773	2 million	Persia
16	Naples plague 1656–1658	1.25 million	Southern Italy
17	Third cholera pandemic 1846–1860	1 million +	Worldwide
18	Italian plague 1629–1631	1 million	Italy
	1889–1890 flu pandemic 1869–1890	1 million	

COVID-19 vs influenza

Both the coronavirus and influenza cause respiratory disease and transmit by droplets, and fomites. Yet there are important differences between the two viruses and how they spread (Table 1.4).

Table 1.4 Differences between corona virus and influenza.

Corona virus	Influenza
The serial interval for COVID-19 virus is estimated to be 5–6 days	Influenza has a shorter median incubation period (the time from infection to appearance of symptoms) and a shorter serial interval (the time between successive cases) Influenza virus, the serial interval is 3 days
There are cases who can shed COVID-19 virus 24–48 h prior to symptom onset	Transmission of the virus before the appearance of symptoms is a major driver of transmission for influenza
The number of secondary infections generated from one infected individual is understood to be between 2 and 2.5 for COVID-19 virus	In case of influenza the secondary infections generated from one infected individual is less than that of corona virus
COVID-19 virus, initial data indicates that children are less affected than adults and that clinical attack rates in the 0–19 age group are low. Further preliminary data from household transmission studies in China suggest that children are infected from adults, rather than vice versa	Children are important drivers of influenza virus transmission in the community
For COVID-19, data to date suggest that 80% of infections are mild or asymptomatic, 15% are severe infection, requiring oxygen and 5% are critical infections, requiring ventilation	Fractions of severe and critical infection is lesser in influenza
Older age and underlying conditions increase the risk for severe infection	Risk for severe influenza infection are children, pregnant women, elderly, those with underlying chronic medical conditions

COVID-19

Outbreak

Retrospective investigations by Chinese authorities have identified human cases with the onset of symptoms in early December 2019. While some of the earliest known cases had a link to a wholesale food market in Wuhan.

On 30 January, WHO declared the COVID-19 outbreak a public health emergency of international concern (PHEIC), as the highest level of alarm. At that time, there were 98 cases and no deaths in 18 countries outside China.

On 11 March, WHO declared COVID-19 as a pandemic due to its rapid spread all around the world. By then, more than 11,800 cases and 4292 deaths in 114 countries had been reported. Surprisingly, by mid-March 2020, WHO European Region had become the epicenter of the epidemic, reporting over 40% of globally confirmed cases. As of April 28, 2020, 63% of global mortality from the virus was from the region. By April 2021, the total cases were reported about 138, 199,138; total deaths 2,975,571; and total recovered 111,170,872.

Structure

Genotypically, animal and plant viruses are two types. Herpes, wart viruses, and adenovirus contain long DNA molecules, whereas coronavirus has RNA as genetic material. Human coronaviruses' particles are spherical, 120–160 mm diameter, are named for their "sun-like" shape observed in the electron microscope. Influenza virus, HIV, rhinoviruses (common cold), SARS-CoV-2 (COVID-19) also contain RNA as genetic material. Onwards, we will be giving emphasis and restricted our discussion on the structure of CORONA-19, and how it attacks host cells.

The COVID-19 consists of RNA polymers tightly enveloped with protective protein molecules known as capsid proteins. In coronavirus, these proteins are called nucleocapsid (N). The core particle of coronavirus is further surrounded by an outer membrane envelope made of lipid (fat) with proteins inserted. This membrane is derived from the cells in which the virus was last assembled, and modified to contain specific viral proteins, including the spike (S), membrane (M), and envelope (E) proteins. A specific set of the proteins are projected on the outer surface of the particle and are known as spike proteins (S). The spike (S) protein has two subunits, e.g., the S1 subunit and S2 subunit. The S1 subunit has a receptor-binding domain that binds with the host cell receptor containing angiotensin-converting enzyme 2, and the S2 subunit mediates fusion between the viral and host cell membranes (Fig. 1.21).

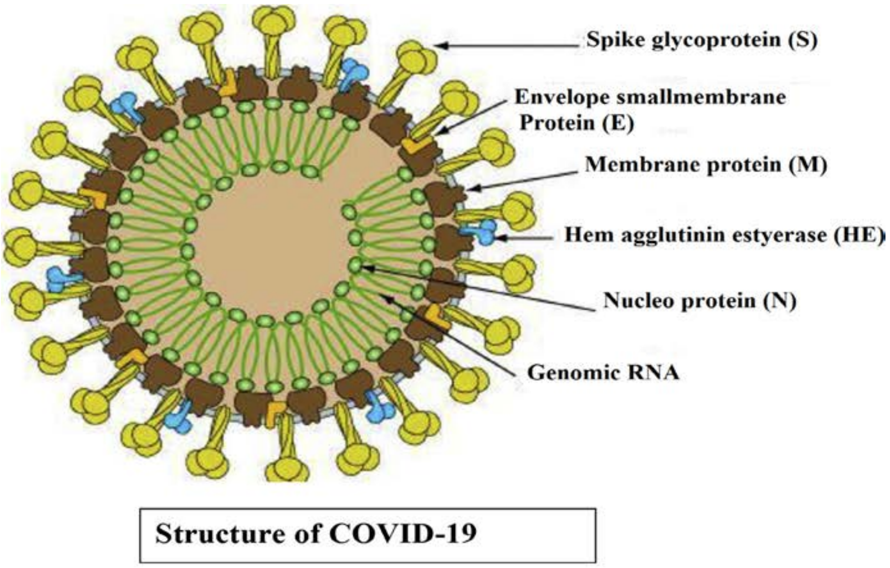
Receptor binding

The S1 subunit has a receptor-binding domain that binds with the host cell receptor containing angiotensin-converting enzyme 2, and the S2 subunit mediates fusion between the viral and host cell membranes. Based on genome sequencing and pair wise protein sequence analysis, 2019-nCoV is recognized as SARC-related coronaviruses [26].

The viral genes can then enter the host cell to be copied, producing more viruses. Alike the SARS-2002, SARS-CoV-2 spikes bind to receptors on the human cell surface called angiotensin-converting enzyme 2 (ACE2). The SARS-CoV-2 spike was 10–20 times more likely to bind ACE2 on human cells than the spike from the SARS virus from 2002. This may enable SARS-CoV-2 to spread more easily from person to person than the earlier virus.

The SARS-CoV-2 (COVID-19) diffuses by respiratory droplets, as it was already demonstrated for other pathogens such as SARS-CoV, Middle East respiratory syndrome coronavirus (MERS), and influenza viruses [27–29]. The SARS-CoV-2 spike glycoprotein binds to ACE-2 and forms a potential target for developing specific drugs, antibiotics, and vaccines. It is also helpful in keeping a balance between RAS and ACE2/MAS [26,30–35]. Both 2019-nCoV and SARS-CoV enter the host cells via the same receptor, angiotensin-converting enzyme (ACE_2). Therefore, this virus was subsequently renamed SARS-CoV-2.

ACE2 mediates SARS-CoV-2 (COVID-19). COVID-19 enters the human body mainly through the SCE2+ TMPRSS2+ nasal epithelial cells (Fig. 1.22). The nasopharynx-associated lymphoid tissues (NALT) system is mainly responsible to first recognize exogenous airborne agents.



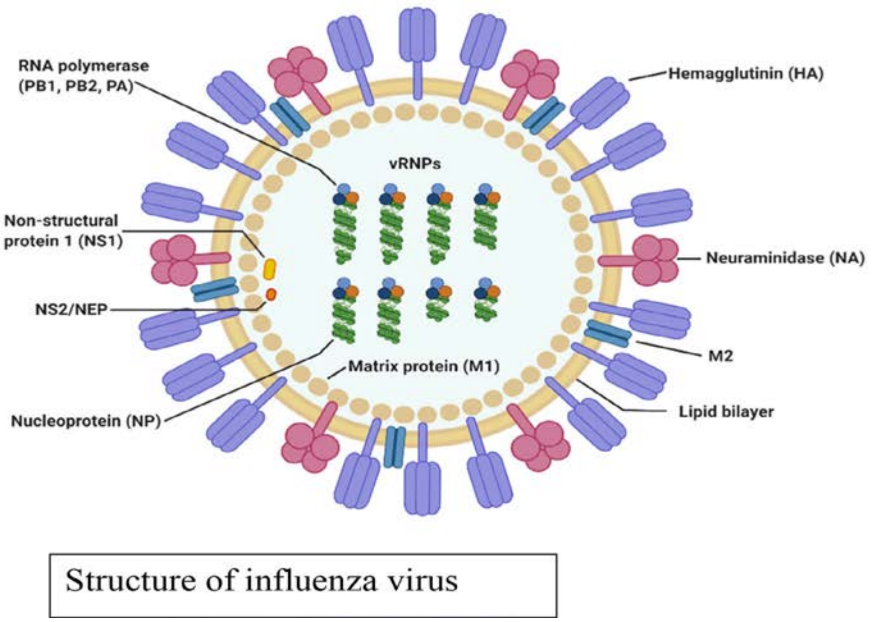


FIG. 1.21

Structure of COVID-19 virus as compared to the structure of influenza virus.

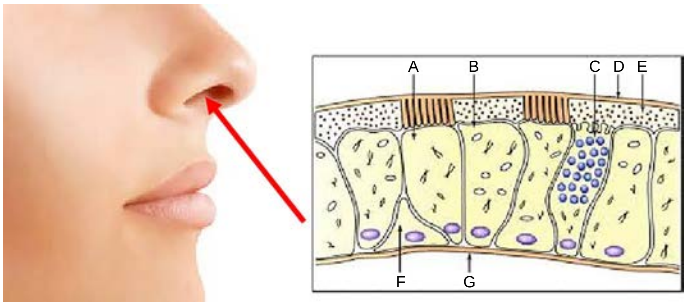


FIG. 1.22

Entry of epithelial cell of nose for CORONA virus.

The olfactory epithelium, found within the nasal cavity, contains olfactory receptor cells, which have specialized cilia extensions. The cilia trap odor molecules as they pass across the epithelial surface.

The NALT represents an immune system of the nasal mucosa and is a part of mucosa-associated lymphoid tissue (MALT) in mammals. It protects the body from airborne viruses and other infectious agents.

The nose represents an important component of the mucosal immunity in upper airways (UA) and is responsible for host protection and immune homeostasis between the commensal microbiota and invading pathogens (Fig. 1.22). The nose and NALT play a central role in the induction of mucosal immune responses, including the generation of Th1- and Th2- polarized lymphocytes and IgA-committed B cells [36–38].

Besides this, other cellular components such as dendritic cells (DCs), microfold (M) cells, and macrophages, nasal epithelial ciliated, and goblet cells are also associated within the induction of the local and systemic response to a wide range of pathogens and allergens (Fig. 1.23) [39].

In infection, the coronavirus particle serves three important functions for the genome: first, it provides the means to deliver the viral genome across the plasma membrane of a host cell; second, it serves as a means of escape for the newly synthesized genome; third, the viral particle functions as a durable vessel which protects the genome integrity on its journey between cells [40].

The infection of coronavirus with special reference to COVID-19 performs three important functions for genomes: (i) it provides the means to deliver the viral genome across the plasma membrane of a host cell, (ii) it serves as a means of escape for newly synthesized genome, and (iii) the viral particles function as a durable vessel which protects the genome integrity on its journey between cells [40].

The novel coronavirus SARS-CoV-2 (COVID-19) attacks the human body mainly through ACE2 + TMPRSS2 + nasal epithelial cells. The NALT acts as an immune system to first recognize exogenous airborne agents. In the human body, it is located in the most cranial pharyngeal mucosa. In addition, being in direct physical contact with the external environment, and rudely filters, moistens, and warms the inhaled

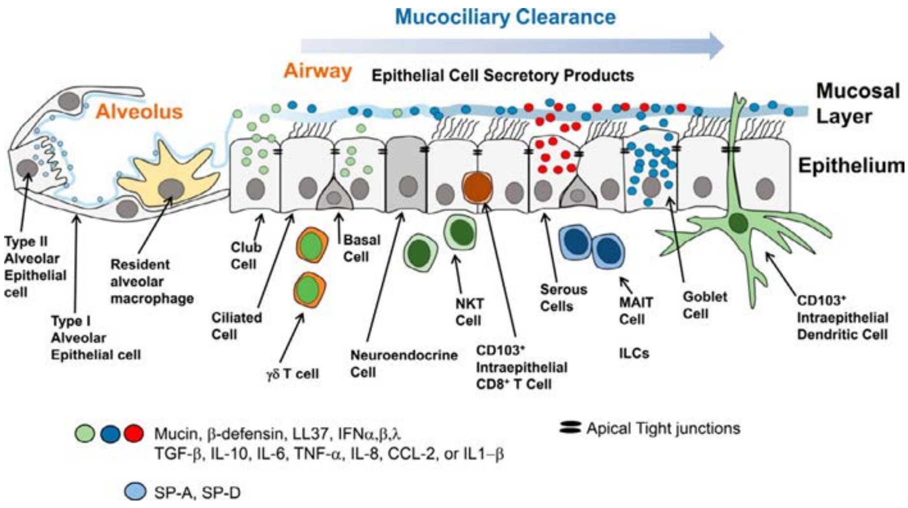


FIG. 1.23

The respiratory epithelium, and relevant epithelial-associated immune cells and soluble factors involved in IAV infection.

With courtesy from Takeda, K. et al. Allergic conversion of protective mucosal immunity against nasal bacteria in patients with chronic rhinosinusitis with nasal polyposis. J Allergy Clin Immunol 2019;143:1163–1175.

air to minimize the irritative effects on lower airways, to maintain the mucociliary clearance and to favor gaseous exchanges.

Following are few important steps on how the coronavirus (COVID-19) attack the human host cells, and subsequently complete its life cycle inside the host cells, before emerging out from the infectious cells.

Step 1

The viral spike (S) binds with ACE2 protein present on the surface membrane of epithelial cells and leads the virion into the host cells. ACE2 is an angiotensin-converting enzyme 2 that acts as a receptor for coronaviruses, including COVIS-19. ACE2 is commonly known as a cellular doorway for coronaviruses (Fig. 1.24).

ACE2 has diversified activities like regulation of angiotensin II (ANGII) which is responsible for increasing blood pressure and inflammation, causing damage to blood vessels linings and different types of tissue injury. ACE2 reduces the harmful effect of ANGII present in the epithelial cells of host cells. When SARS-CoV-2 + ACE2 form a complex and prevent ACE2 from performing its normal function to regulate ANGII signaling. As a result, more ANGII are available and responsible for causing injury, especially to the lungs and heart, in COVID-19 patients. ANGII can increase inflammation and the death of cells in the alveoli which are critical for bringing oxygen into the body; these harmful effects of ANGII are reduced by ACE2 (Fig. 1.25). The sequential steps involved in pathway of coronavirus (COVID-19) are as follows (Fig. 1.26).

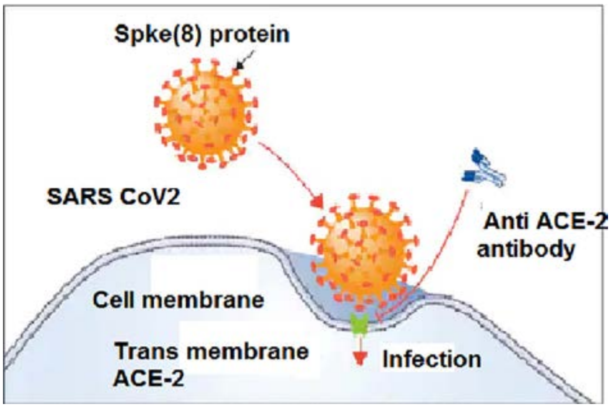


FIG. 1.24

Showing how ACE2 acts as the receptor for the SARS-CoV-2 virus and allows it to infect the cell.

Step 1

The virion attaches to the ACE2 present on the surface of host cells. The nucleocapsid plays a critical role in enhancing the efficiency of virus transcription and assembly. The nucleocapsids protect the genome and ensure its timely replication and reliable transmission.

Step 2

The virion + ACE2 enters the cytoplasm by fusion of the membrane of host cells and virion surface protein (S).

Step 3

The virion gets into the lysosome, and by the interaction with liposomal enzymes it releases genomic ssRNA and nonorganized capsid proteins.

Step 4

The genome RNA (+ sence) and capsid get into the cytoplasm.

Step 5

The nonstructural proteins get released. The N protein is thought to bind the genomic RNA in a beads-on-a-string fashion on the surface of the endoplasmic reticulum. It plays a key role in improving the efficacy of virus transcription and assembly.

Step 6

The genomic ssRNA and beaded proteins migrate toward the Golgi body.

Step 7

Release of progeny virion.

Here, the translation of the viral positive-sense single-stranded RNA (+ ssRNA) and cleavage of the translation product into specific viral protein occur. The entire process is carried by liposomes.

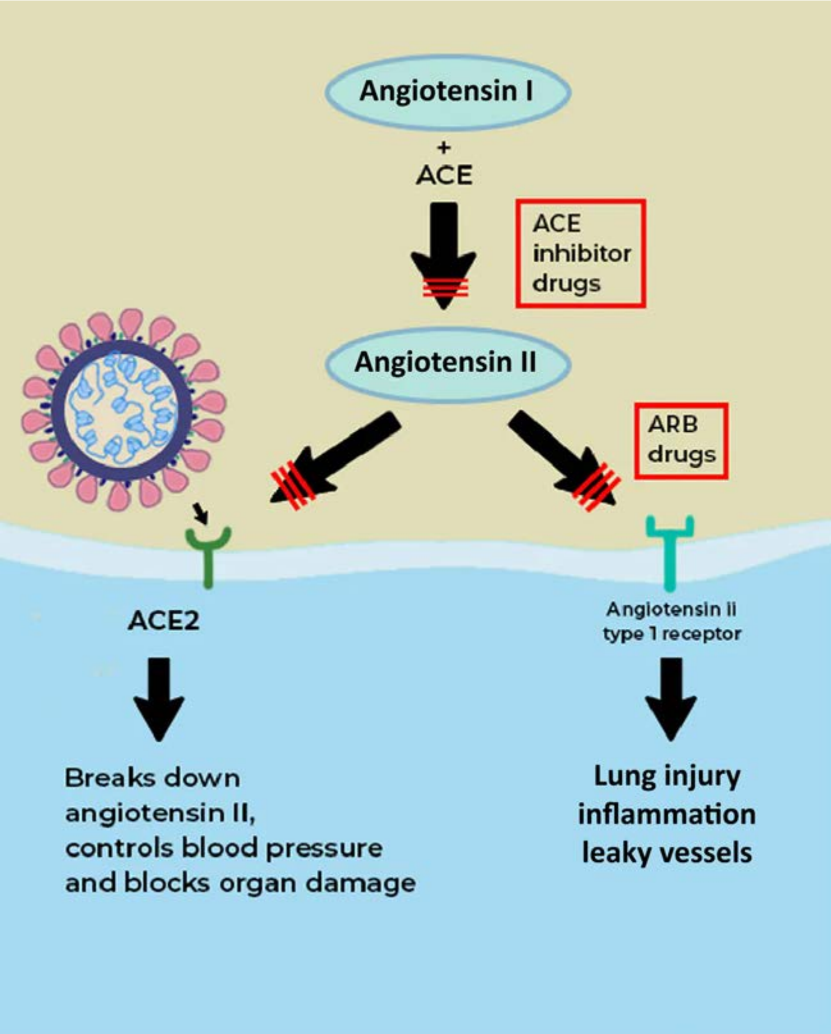


FIG. 1.25

ANGII increase inflammation and death of cells in the alveoli.

As discussed above, coronaviruses (COVID-19) have a high potential for genomic nucleotide substitution rates and recombination. The COVID-19 virus continues its propagation through host cells by keeping its genome expression system in intact form along with virus particles assembly and virion progeny release. Research is in progress to develop the safest and secure vaccine as a preventive measure for COVID-19 contamination.

In COVID-19, the rate of error during RNA replication (about 10^{-4}) is greater than that of DNA (about 10^{-5}). The RNA virus neither has the proofreading

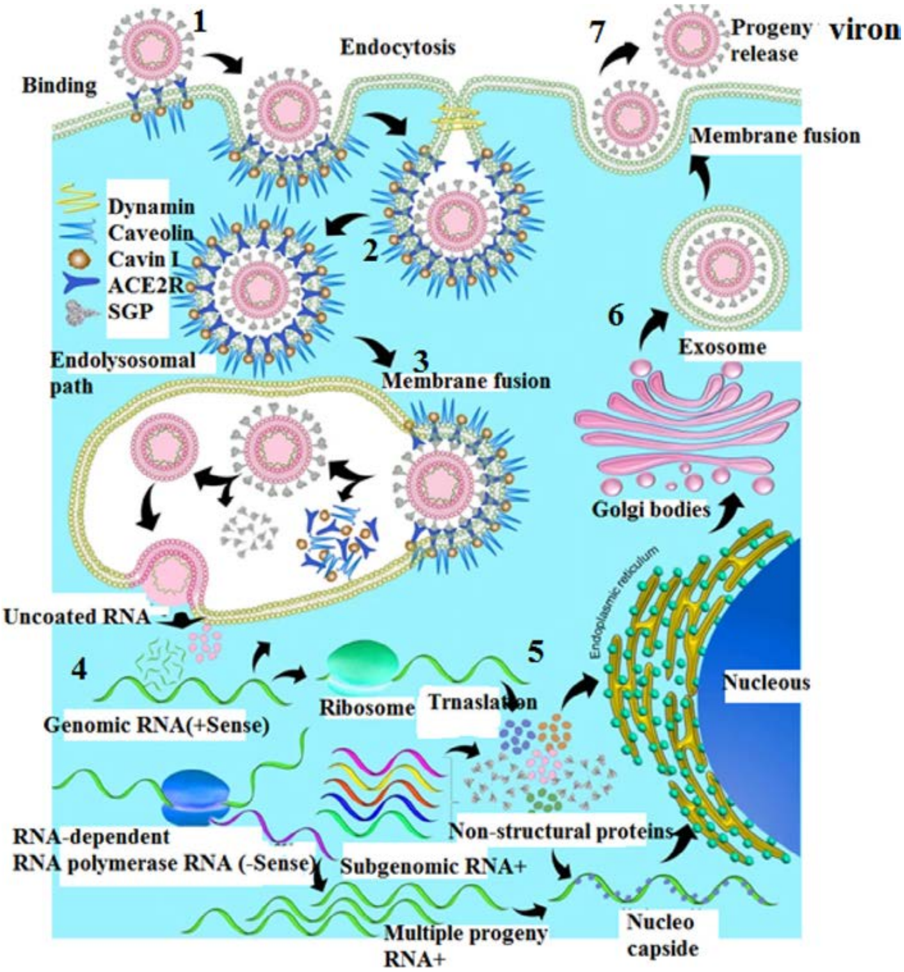


FIG. 1.26

The various steps involved in path way of coronavirus (COVID-19).

capabilities nor postreplication mismatch repair mechanism as one can do with DNA polymerase. So, the potential for mutation per replication cycle of an RNA genome is high [41]. Due to high mutation and recombination rates, coronavirus (COVID-19) can easily cross species barriers and adapt to new hosts [42].

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