

# **HUMAN BIOLOGY**

**Seventeenth Edition**

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## **Chapter 8 Biology of Infectious Diseases**

# 8.1 Bacteria and Viruses <sub>1</sub>

## Learning Outcomes:

- Define the term *pathogen*.
- Identify the structures of a prokaryotic cell.
- Describe the general structure of a virus.

# 8.1 Bacteria and Viruses 2

**Microbes**—microscopic organisms, such as bacteria, viruses, and protists.

Widely distributed in the environment, on inanimate objects and living things.

Many are useful to humans.

- Bacteria contribute to the production of yogurt, cheese, bread, beer, wine, and many pickled foods.
- Drugs are produced by bacteria.
- Without the activity of decomposers, the biosphere wouldn't exist.

# 8.1 Bacteria and Viruses 3

**Pathogens**—disease-causing agents.

Bacteria, viruses, and others.

Defenses against pathogens:

- Barriers to prevent pathogens from entering the body (skin, mucous membranes).
- Phagocytic WBCs fight infection after a pathogen gets past the barriers and into the body.
- Acquired defenses kill pathogens and protect against cancer.

# Bacteria<sub>1</sub>

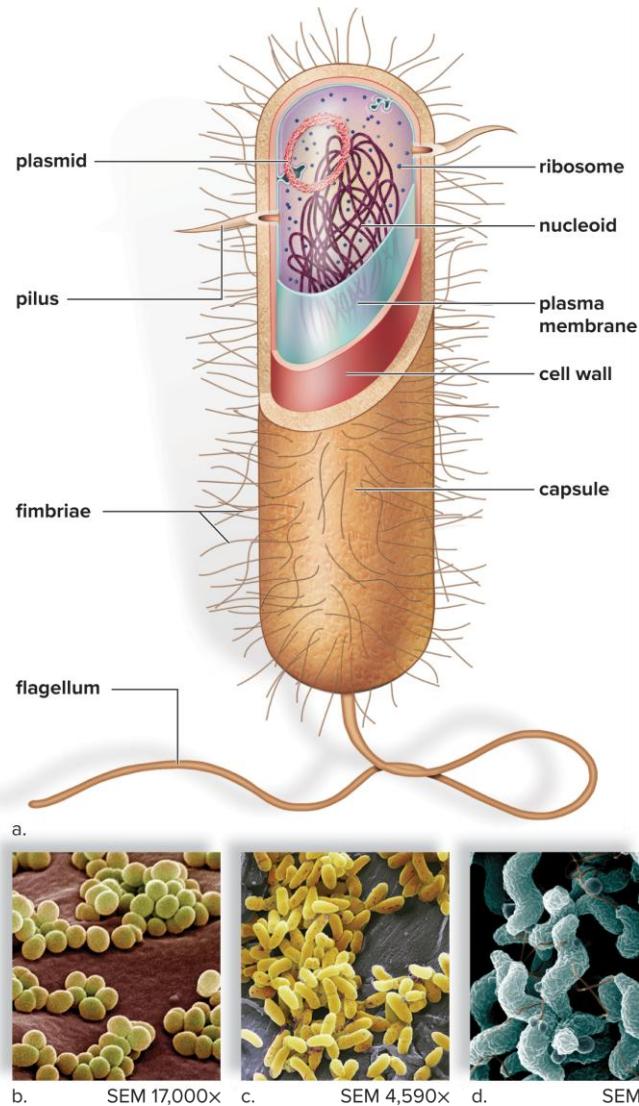
**Bacteria**—single-celled, prokaryotic organisms.

Three common shapes: **coccus** (sphere-shaped), **bacillus** (rod-shaped), and **spirillum** (curved, sometimes spiral-shaped).

Most have a **cell wall** in addition to the plasma membrane.

- Cell wall contains **peptidoglycan** (a disaccharide with an amino group).
- Some antibiotics, such as penicillin, interfere with the production of the cell wall.
- Some are surrounded by a **capsule** that allows bacteria to stick to surfaces and protects them.

# Typical Shapes of Bacteria (Figure 8.1)



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# Bacteria <sub>2</sub>

## Bacteria, continued.

Bacteria are classified by differences in their cell walls, which are detected using **Gram stain**.

- Cell walls that have a thick layer of peptidoglycan stain purple with Gram stain; are called **Gram-positive bacteria**.

If no peptidoglycan layer, the cells stain pink and are considered **Gram-negative**.

- These bacteria have an outer membrane with **lipopolysaccharides**, which are released when cells are killed by the immune system, stimulating inflammation and fever.

# Bacteria <sub>3</sub>

## Bacteria, continued.

Motile bacteria usually have long, very thin appendages called **flagella** (*sing.*, flagellum).

- The flagella move the bacterium.

Some bacteria have **fimbriae**—stiff fibers that adhere them to surfaces such as host cells.

- Fimbriae allow a bacterium to gain access to the body.

**Pilus**—elongated, hollow appendage used to transfer DNA from one cell to another.

- Genes that give bacteria resistance to antibiotics can be passed through a pilus by **conjugation**.

# Bacteria <sub>4</sub>

## **Bacteria, concluded.**

DNA is packaged in a chromosome in the center of the cell.

Many bacteria also have small, circular pieces of DNA called **plasmids**.

- Genes that give bacteria resistance to antibiotics are often located in a plasmid.

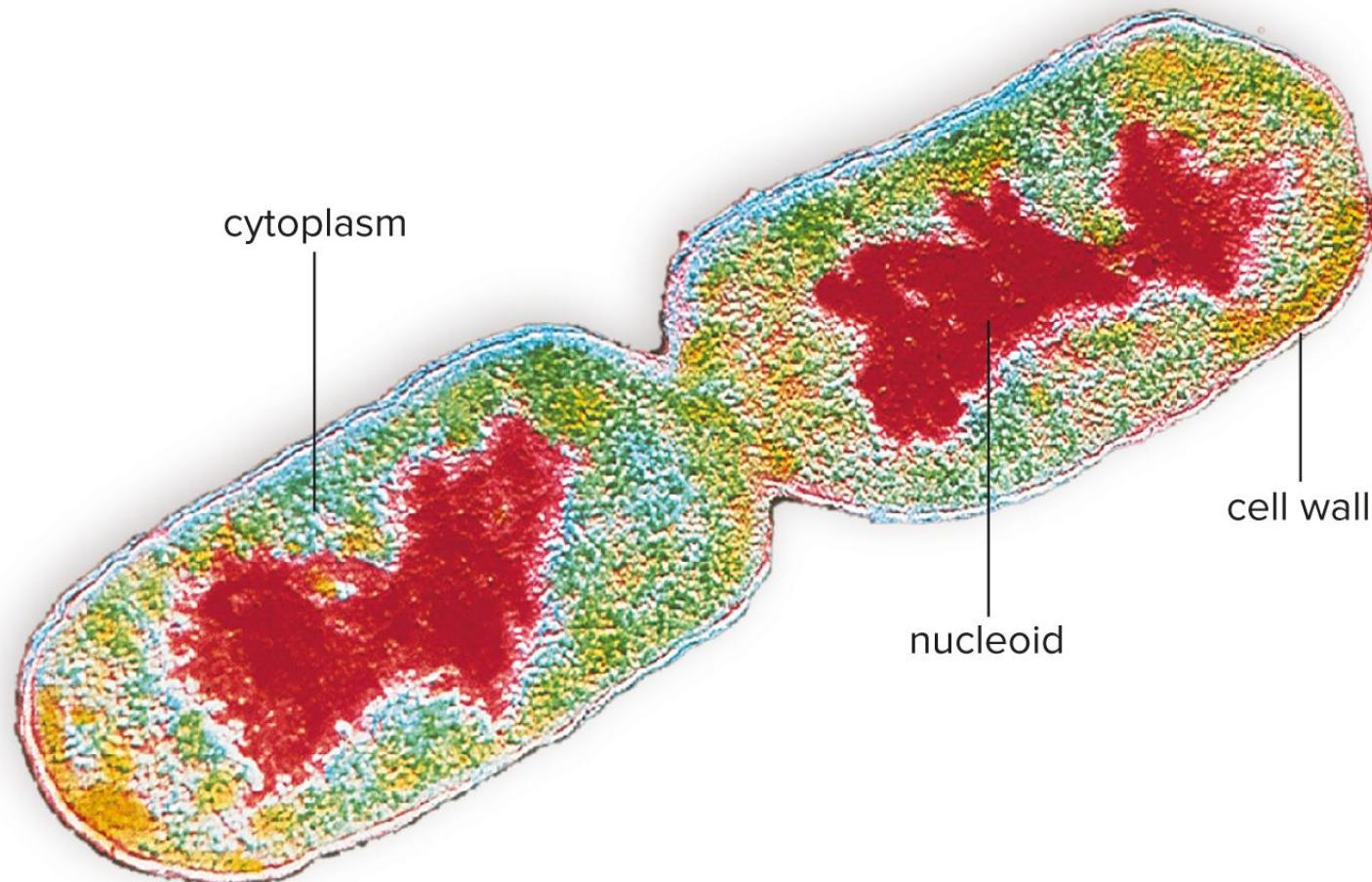
Abuse of antibiotics increases the number of resistant bacterial strains that are difficult to kill.

# Bacteria <sub>5</sub>

## **Binary fission—how bacteria reproduce.**

- The single, circular chromosome attached to the plasma membrane is copied.
- Then the chromosomes are separated as the cell enlarges.
- The cell separates into two cells.
- Can reproduce rapidly under favorable conditions; some can double their numbers every 20 minutes.

# Binary Fission (Figure 8.2)



# Bacteria <sub>6</sub>

## Binary fission, continued.

Strep throat, tuberculosis, gangrene, gonorrhea, and syphilis are well-known bacterial diseases.

Not only does growth of bacteria cause disease, but some bacteria release toxins that inhibit cellular metabolism.

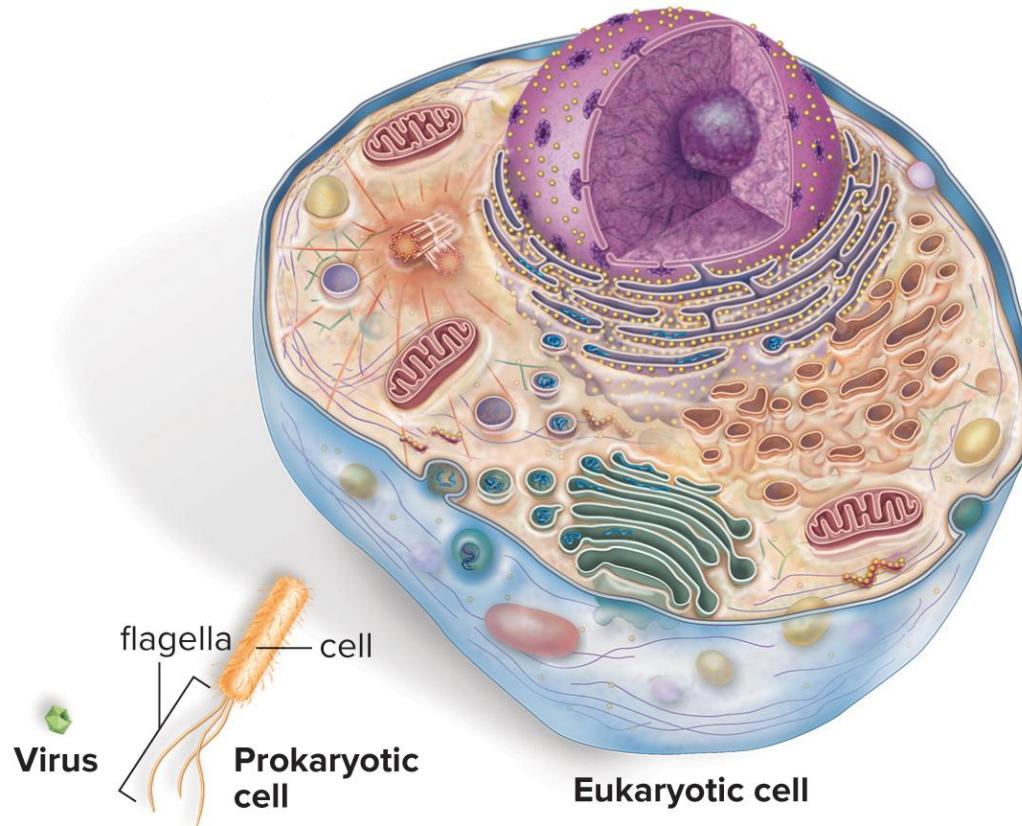
- That is, a tetanus shot protects against *Clostridium tetani*, which produces a toxin that prevents relaxation of muscles.
  - In time, all the muscles contract, causing suffocation.

# Viruses<sub>1</sub>

## Viruses.

- Very small, intracellular parasites.
- Nonliving (acellular); must reproduce inside of a host cell.
- Two parts: an outer protein coat called a **capsid** and nucleic acid (RNA or DNA) inside.
- Carry the genetic information needed to reproduce.

# Comparative Sizes of Viruses, Bacteria, and Eukaryotic Cells (Figure 8.3)



# Viruses <sub>2</sub>

## Viruses, continued.

- In contrast to cellular organisms, viral genetic material can be DNA or RNA.
- Cellular parasites; commandeer the metabolic machinery of a host cell.

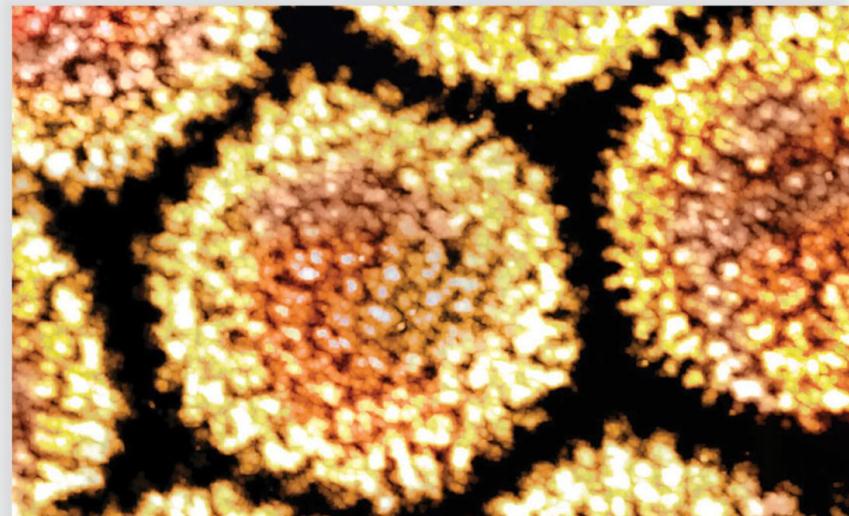
# Viruses<sub>3</sub>

## Viruses, concluded.

Portions of the virus bind to a receptor on the host cell's surface.

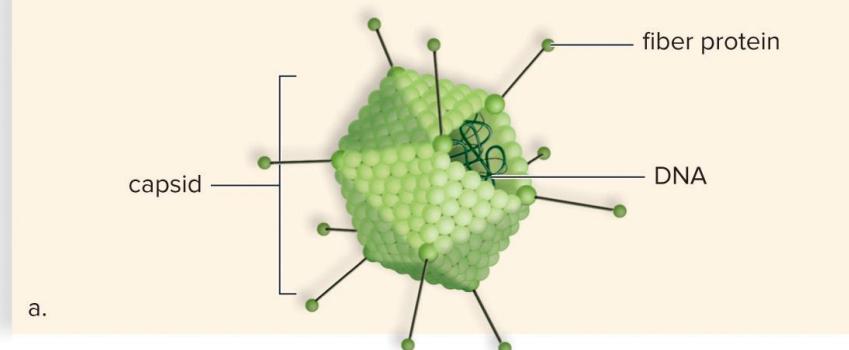
- Once the virus attaches, its DNA or RNA enters the cell and codes for the proteins in the capsid.
- The virus may have genes that code for enzymes needed for the virus to reproduce and exit the host cell.
- A virus relies on the host's enzymes and ribosomes for its own reproduction.

# Typical Virus Structures (Figure 8.4a)



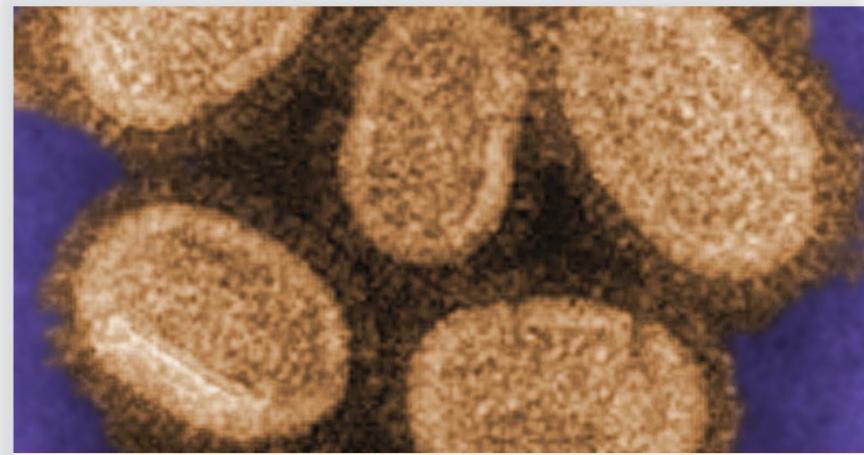
Adenovirus: DNA virus with a polyhedral capsid and a fiber at each corner.

TEM 60,000 $\times$



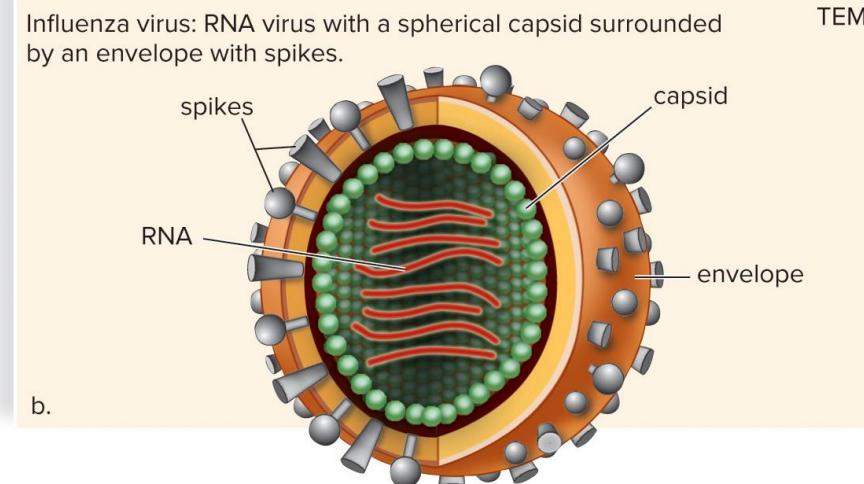
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# Typical Virus Structures (Figure 8.4b)



Influenza virus: RNA virus with a spherical capsid surrounded by an envelope with spikes.

TEM



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# Viruses 4

Life cycle stages of a bacteriophage (virus):

**Attachment**—the capsid of the virus combines with a receptor on the surface of the host cell.

**Penetration**—a viral enzyme digests away part of the cell wall, and the viral genetic material is injected into the bacterial cell.

- Other viruses, entire virus enters the cell by endocytosis.

**Biosynthesis**—the host cell's machinery replicates the virus's genetic material, producing multiple copies of the capsid protein subunits.

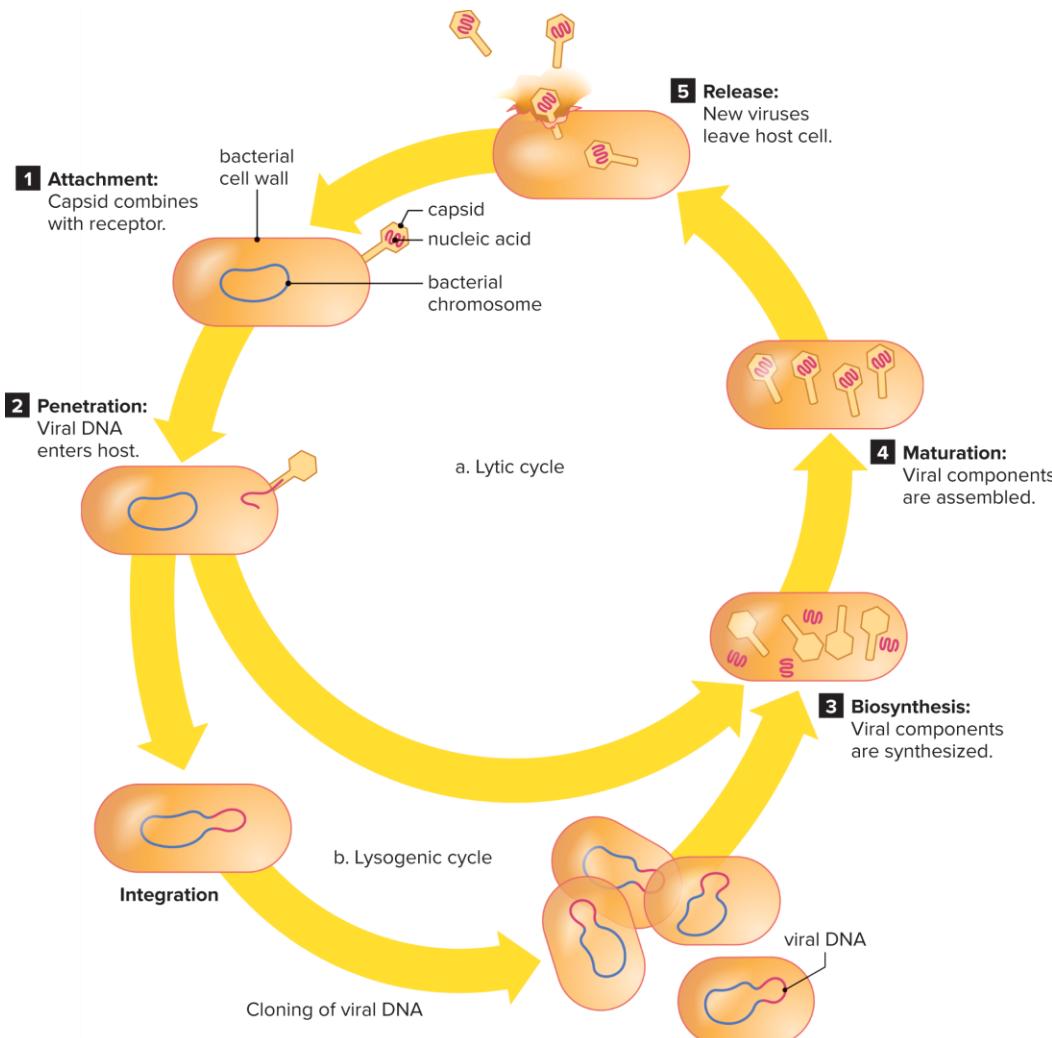
# Viruses 5

Virus life cycle stages, continued:

- **Maturation** (aka assembly)—the viral genetic material and capsids combine, producing several new viruses.
- **Release**—new viruses leave the cell by exocytosis or by disrupting the cell membranes (and cell walls in bacteria), releasing the new viruses.

There are many variations in this cycle, depending on the type of virus.

# General Life Cycle of a Virus (Figure 8.5)



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# Viruses <sub>6</sub>

## Lysogenic cycle.

- Infected cell does not immediately produce new viruses.
- The virus becomes *latent* (it is not actively reproducing) upon entering the host cell.

# Viruses 7

Lysogenic cycle, continued.

Following attachment and penetration, *integration* occurs:

- Viral DNA is incorporated into the host cell (*prophage*).
- DNA is replicated along with host DNA; all subsequent cells (lysogenic cells) carry a copy of the viral information.
- Certain environmental factors (ultraviolet radiation) can induce the prophage to enter the lytic stage of biosynthesis, followed by maturation and release.

# Prions

**Prions—**infectious protein particles.

Cause degenerative diseases of the nervous system.

- That is, Creutzfeldt–Jakob disease (CJD) in humans, scrapie in sheep, and bovine spongiform encephalopathy (BSE) in cattle, commonly called mad cow disease.

Normal forms of proteins fold into abnormal shapes called prions.

- Prions are able to change the shape of other proteins.

# Check Your Progress 8.1

Explain the differences among the structures of a bacterium, a eukaryotic cell, and a virus.

Detail the structures in bacteria that can be associated with the ability to cause disease.

Explain why viruses are considered intracellular parasites.

# 8.2 Infectious Diseases and Human Health

## Learning Outcomes:

- Distinguish among an outbreak, an epidemic, and a pandemic.
- Describe the HIV life cycle.
- Describe the causes of tuberculosis and malaria.

## 8.2 Infectious Diseases and Human Health

An **infectious disease** is classified as an **epidemic** if there are more cases than expected in a certain area for a certain period of time.

A few cases of a very rare disease may constitute an epidemic, whereas a larger number of a very common disease may not.

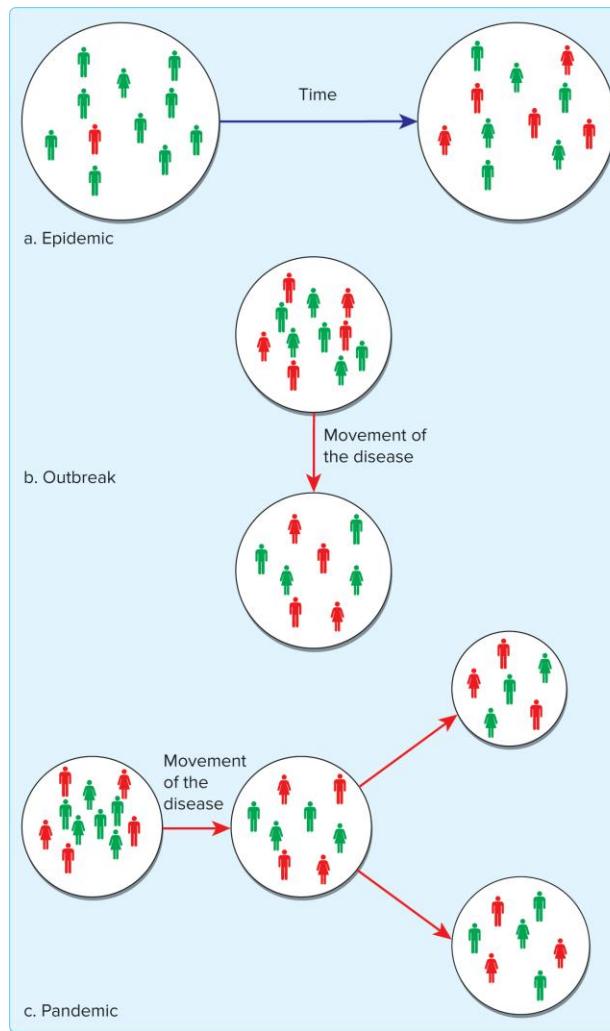
**Outbreak**—an epidemic confined to a local area.

- That is, the 2013–2014 Ebola outbreak in West Africa.

Global epidemics are called **pandemics**.

- That is, HIV/AIDS, SARS-CoV-2/COVID-19, tuberculosis, malaria, influenza; all current.

# Outbreaks, Epidemics, and Pandemics (Figure 8.6)



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# HIV/AIDS <sub>1</sub>

## **Origin of and Prevalence of HIV.**

The exact dates of the first human cases of HIV are still being investigated.

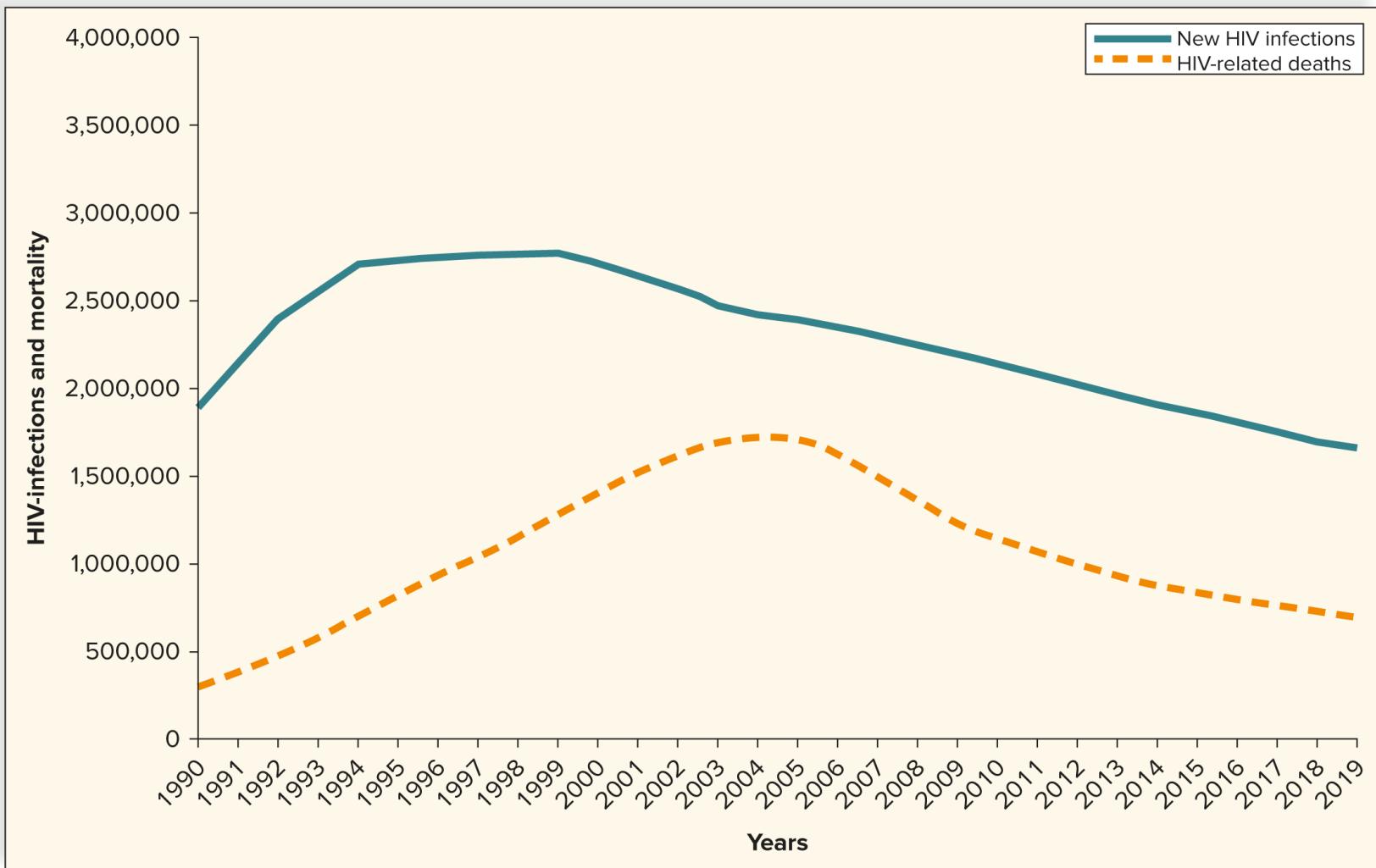
- First human infection was between 1884 to 1924.
- HIV was found in human tissue and blood samples taken in the 1950s and 1960s.
- The name AIDS was coined in 1982, and HIV was found to be the cause of AIDS in 1983 to 1984.

# HIV Global Statistics, 2019 (Table 8.1)

**Table 8.1 HIV Global Statistics, 2019**

	People Living with HIV	New Infections	AIDS Deaths
Eastern and Southern Africa	20.7 million	730,000	300,000
Western and Southern Africa	4.9 million	240,000	140,000
Asia and the Pacific	5.8 million	300,000	160,000
Latin America	2.1 million	120,000	37,000
Caribbean	330,000	13,000	6,900
Western and Central Europe and North America	2.2 million	65,000	12,000
Eastern Europe and Central Asia	1.7 million	170,000	35,000
North Africa and the Middle East	240,000	20,000	8,000
<b>Total</b>	<b>38.0 million</b>	<b>1.7 million</b>	<b>690,000</b>

# HIV/AIDS (Figure 8.7)



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# HIV Structure <sub>1</sub>

## HIV structure.

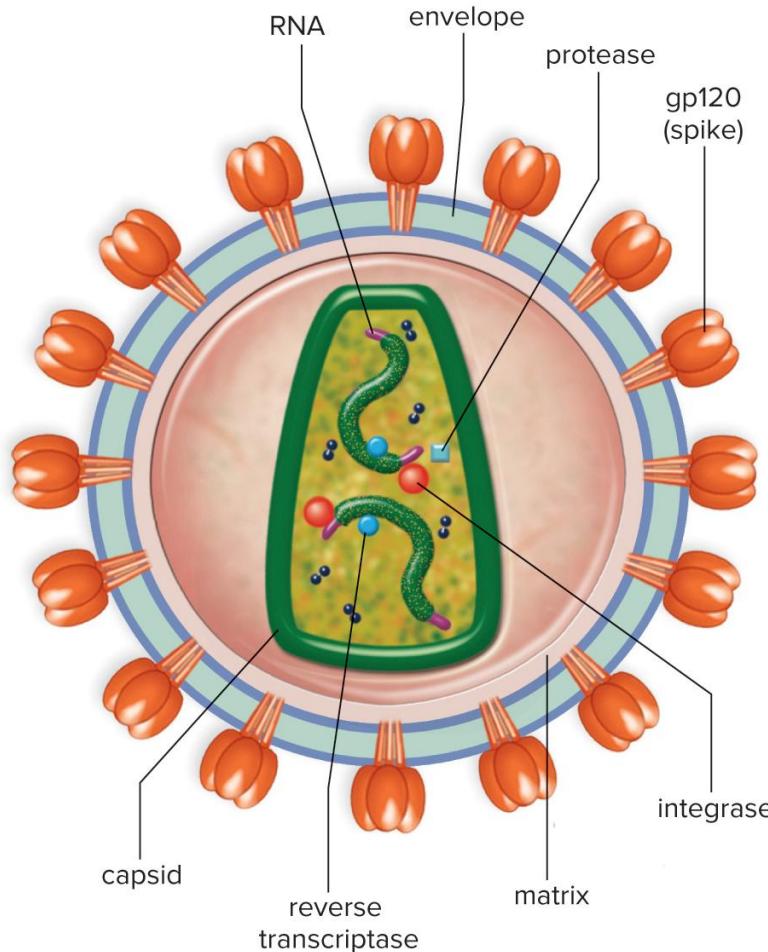
Consists of two single strands of RNA (its genome); various proteins; and an envelope, which it acquires from its host cell.

RNA is protected by three protein coats: the nucleocapsid, capsid, and matrix.

Within the matrix are three enzymes:

- **Reverse transcriptase** converts viral RNA to viral DNA.
- **Integrase** integrates viral DNA into DNA of the host cell.
- **Protease** converts the newly synthesized viral polypeptides into functional viral proteins.

# The Structure of the Human Immunodeficiency Virus (Figure 8.8)



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# HIV Structure <sub>2</sub>

HIV structure, continued.

**gp120s**—protein spikes embedded in HIV's envelope.

- Must be present for HIV to enter its target cells.

**Retrovirus**—a virus with RNA instead of DNA.

- Must use reverse transcription to convert its RNA into DNA before it can insert its genome into the host cell's DNA.

# HIV Life Cycle <sub>1</sub>

Life cycle of HIV.

**Attachment**—HIV binds to its target cell.

- gp120 binds to a CD4 receptor on the surface of a helper T cell or macrophage.

**Fusion**—HIV fuses with the plasma membrane and enters the cell.

**Entry**—during a process called **uncoating**, the capsid and protein coats are removed, releasing RNA and viral proteins into the cytoplasm of the host cell.

# HIV Life Cycle <sub>2</sub>

Life cycle of HIV, continued.

**Reverse transcription**—unique to retroviruses; **reverse transcriptase** converts HIV's single-stranded RNA into double-stranded viral DNA.

**Integration**—The viral enzyme **integrase** integrates the new viral DNA into the host cell's DNA.

- HIV is now called a **provirus** because it is a part of the cell's genetic material.

# HIV Life Cycle <sub>3</sub>

Life cycle of HIV, continued.

## Integration, continued.

- HIV is usually transmitted by cells with proviruses.
- Even if drug therapy results in an undetectable viral load, there are still proviruses inside lymphocytes.

**Biosynthesis and cleavage**—normal cell machinery directs the production of more viral RNA.

- RNA codes for new viral particles and polypeptides that have to be cut up into smaller pieces (“cleavage”).
  - Catalyzed by the **HIV protease** enzyme.

# HIV Life Cycle <sub>4</sub>

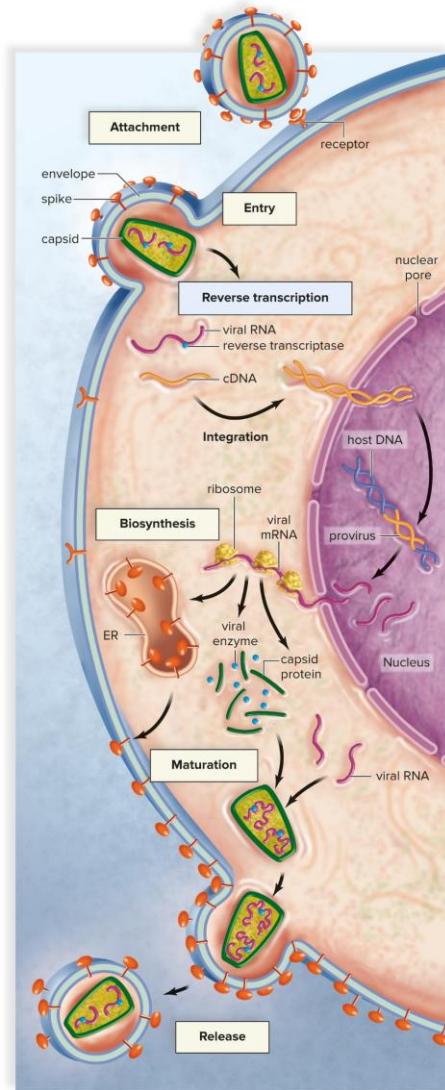
Life cycle of HIV, concluded.

**Assembly**—capsid proteins, viral enzymes, and RNA are assembled into new viral particles.

**Budding**—the new viruses leave the cell.

- The new envelope is actually host cell plasma membrane.

# HIV Replication Cycle (Figure 8.9)



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# HIV Life Cycle <sub>5</sub>

The life cycle of an HIV virus includes transmission to a new host.

Body secretions contain proviruses inside CD4 T cells.

When this fluid comes in contact with the mouth or vagina, for example, infected cells migrate through its lining and enter the body.

- The receptive partner in anal-rectal intercourse appears to be most at risk, because the lining of the rectum is very thin.

# HIV Life Cycle <sub>6</sub>

CD4 macrophages are the first infected when proviruses enter the body.

When these macrophages move to the lymph nodes, HIV begins to infect CD4 T cells.

HIV can hide out in local lymph nodes for some time, but eventually the lymph nodes degenerate.

- Large numbers of HIV particles then enter the bloodstream.

# HIV Vaccine

HIV vaccines in development.

- **Preventive vaccine**—not a cure, but would prevent infection.
- **Therapeutic vaccine**—could slow the progression of the disease on future infection.
- Scientists have studied more than 50 different preventive vaccines and over 30 therapeutic vaccines.

# Tuberculosis <sub>1</sub>

## Tuberculosis (TB).

- Used to be called **consumption**, because it seemed to consume the patients from the inside until they wasted away.
- One-third of the world's population has been exposed to TB.
- Caused by a species of rod-shaped bacterium called *Mycobacterium tuberculosis*.

# Tuberculosis<sup>2</sup>

## Tuberculosis (TB), continued.

Spread by droplets introduced into the air when an infected person coughs, sings, or sneezes.

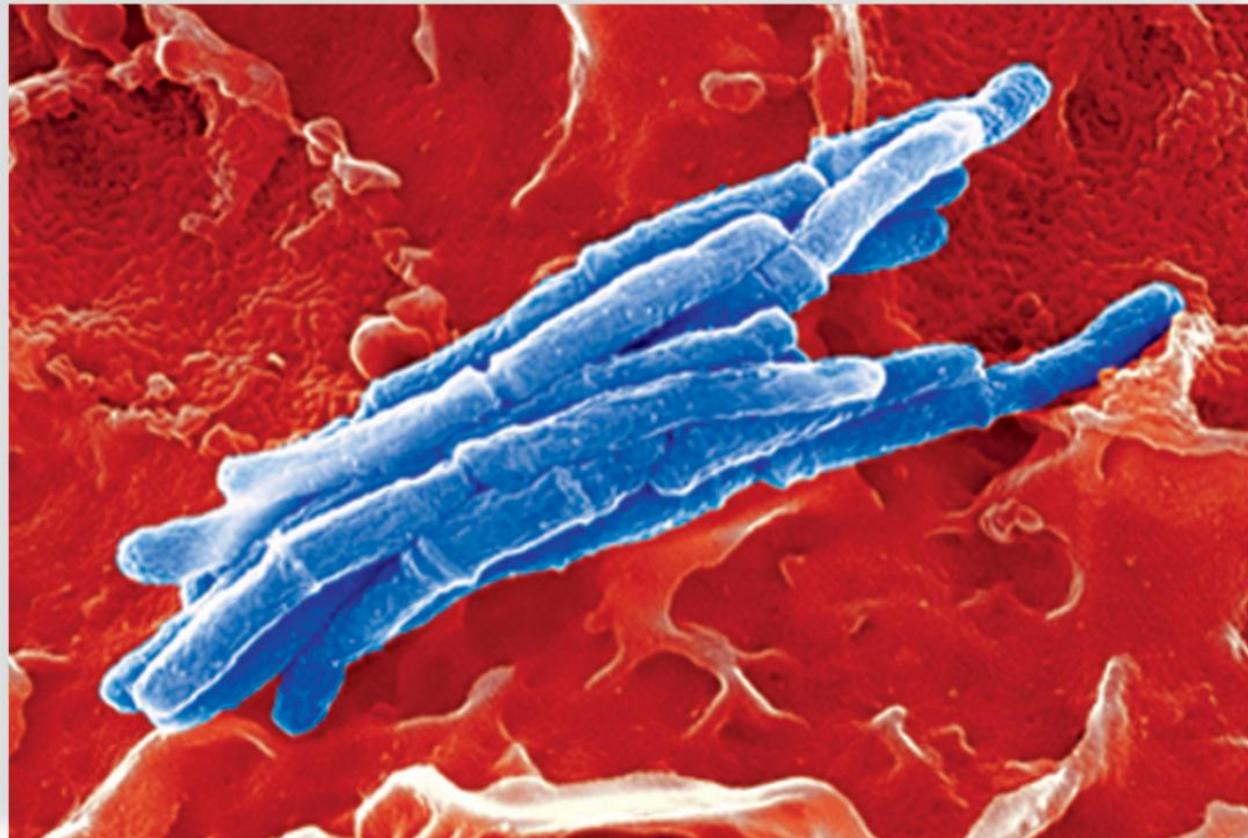
- Can float in the air for hours and still be infectious.

Incubation period is 4 to 12 weeks; develops very slowly.

In the lungs, it is consumed by macrophages.

- Other white blood cells rush to the infected area; together they wall off the original infection site, producing small, hard nodules, or tubercles, in the lungs.

# The Causative Agent of Tuberculosis (Figure 8.10)



SEM 6,200 $\times$

# Tuberculosis 3

## Tuberculosis (TB), concluded.

The bacteria remain alive within the tubercles, but the disease does not progress.

These patients are said to have latent TB.

- They do not feel sick, and are not contagious.
- They test positively on a TB skin test.
- Tubercles often calcify and can be seen on a chest X-ray.

# An X-Ray of a TB-Infected Lung (Figure 8.11)



# Symptoms of Tuberculosis

## Symptoms of tuberculosis.

In a person with active disease, the tubercle liquefies and forms a cavity.

- The bacteria can then spread from these cavities throughout the body; it can be fatal.

Symptoms of active TB include a bad cough, chest pain, and coughing up blood or sputum.

- As the disease progresses, symptoms include fatigue, loss of appetite, chills, fevers, and night sweats.
- The patient begins to lose weight, wastes away.

# Treatment of Tuberculosis

Treatment of tuberculosis.

Due to the resurgence of antibiotic-resistant strains, multiple anti-TB drugs are given simultaneously for 12 to 24 months.

There are several drug-resistant forms of TB.

- That is, multidrug-resistant TB (MDR TB) and extensively drug-resistant TB (XDR TB).

It takes at least 6 months to kill all the tuberculosis bacteria in the body.

# Malaria<sub>1</sub>

## Malaria.

- The geographic distribution of malaria is explained by the mosquito vector that depends on temperature and rainfall.
- A **vector** is a living organism—usually an insect or animal—that transfers the pathogen from one host to another.
- The parasites that cause malaria belong to the genus *Plasmodium*, which are protists.
- There are four species that infect humans.

# Malaria <sub>2</sub>

## **Malaria, continued.**

As the female mosquito feeds on human blood, she injects saliva containing an anticoagulant along with the parasite.

The parasites infect liver cells and red blood cells.

Symptoms range from very mild to fatal.

- Most develop a flulike illness (chills, fevers, sweating).
- Exhibit a cyclical pattern every 48 to 72 hours.

Mosquito nets and antimalarial drugs are used to prevent and treat malaria.

# Influenza

## Influenza (flu).

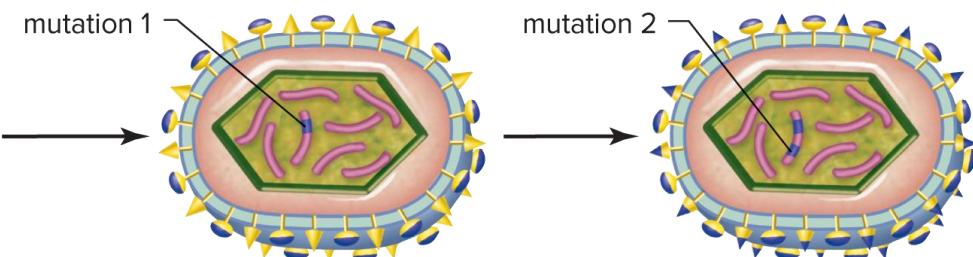
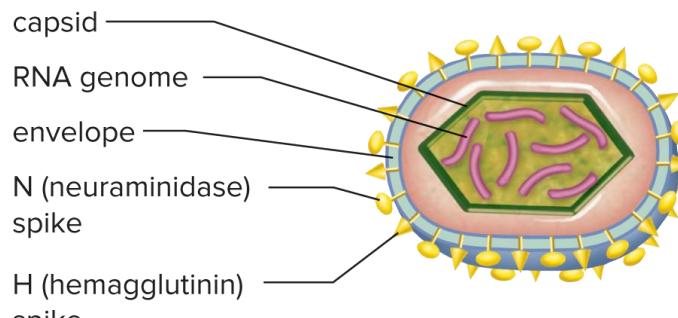
Affects 5 to 20% of Americans each year and causes an estimated 36,000 fatalities.

Viral infection that causes runny nose, cough, chills, fever, head and body aches, nausea.

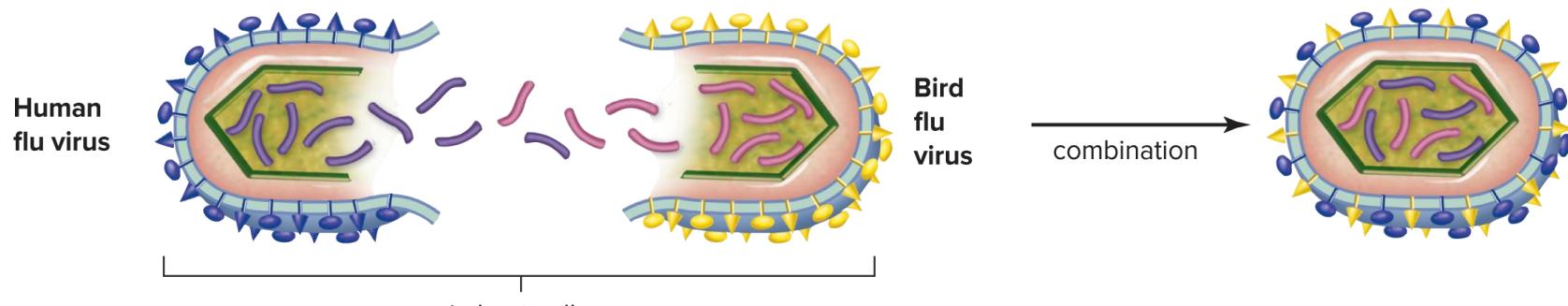
You can catch it by inhaling virus-laden droplets or by contact with contaminated objects.

- The viruses then attach to and infect cells of the respiratory tract.

# The Bird Flu Virus (Figure 8.12)



a. Viral genetic mutations occur in a bird host.



b. Combination of viral genes occurs in human host.

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# Check Your Progress 8.2

Describe the differences among an outbreak, an epidemic, and a pandemic, and give an example of each.

Summarize the HIV replication cycle, and list the types of cells this virus infects.

Explain the role of the mosquito in the malarial life cycle.

Explain how variation may occur in influenza viruses such as H5N1.

# 8.3 Emerging Diseases and COVID-19 <sup>1</sup>

## Learning Outcomes:

- Define the term *emerging disease*.
- List some examples of emerging diseases.

## 8.3 Emerging Diseases and COVID-19 <sup>2</sup>

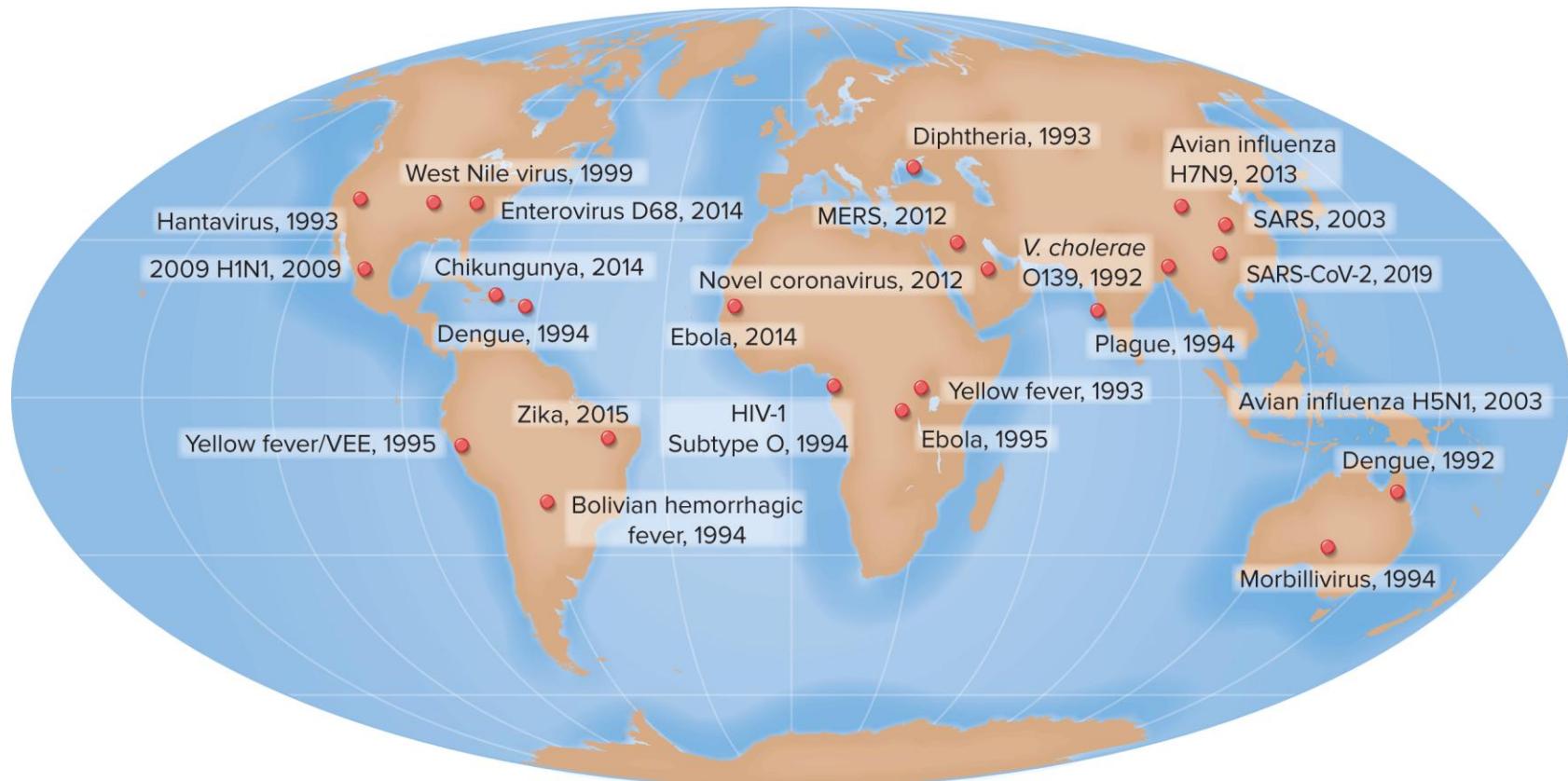
**Emerging diseases**—occur for the first time in humans, are rapidly becoming more common in humans, or are entering into new geographic regions.

- Avian influenza (H5N1), swine flu (H1N1), and Middle East respiratory syndrome (MERS), Zika, SARS-CoV-2.

**Reemerging diseases**—reappear after a significant decline in incidence.

- Sample pathogens: *Streptococcus*, *Helicobacter pylori*.

# Emerging Diseases (Figure 8.13)



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# COVID-19<sup>1</sup>

**Coronaviruses**—named for their crown-like spikes emerging from the virus's surface.

A common animal virus (zoonotic virus) that may infect various animal species.

- That is, bats, camels, birds, livestock, humans.
- First human infections were in the 1950s, associated with mild cases of the common cold.

Coronaviruses may cause respiratory and intestinal diseases in livestock (chickens, pigs, cattle).

- In humans, it's the SARS/MERS class of viruses that cause diseases.

# COVID-19 <sub>2</sub>

**SARS-CoV**—a more severe form of human coronavirus, with a fatality rate just under 10%.

Thought to have originated in bats or civet cats, then transmitted to humans.

Appeared in China in 2002 then spread, causing a global outbreak in 2003, with no further human cases reported since 2004.

- Over 8,000 known cases and 774 deaths worldwide.

# COVID-19 <sub>3</sub>

**Middle East respiratory syndrome (MERS)**—a type of coronavirus, known to cause respiratory problems.

- Precise animal host is unknown, but has been found in camels and bats.
- Can be transmitted between individuals by close contact.
- Causes pneumonia and kidney failure, and has a 34.4% mortality rate.

# COVID-19 <sub>4</sub>

**SARS-CoV-2** (originally called 2019-nCoV and Novel Coronavirus 2019)—new coronavirus that causes the respiratory disease **COVID-19**.

Emerged in the Wuhan province of China.

Highly contagious.

- Quickly became a global pandemic.
- Hundreds of millions infected; ever-increasing death toll.
- Caused global disruption of society by impacting travel, economies, and social interactions.

# Check Your Progress 8.3

Distinguish between an emerging disease and a reemerging disease.

Explain how emerging diseases arise.

Explain what may be done to reduce the threat of emerging and reemerging diseases.

# 8.4 Antibiotic Resistance <sub>1</sub>

## Learning Outcomes:

- Summarize how a pathogen becomes resistant to an antibiotic.
- Explain the significance of antibiotic resistance.

## 8.4 Antibiotic Resistance <sup>2</sup>

### **Antibiotic resistance.**

Antibiotic use does not cause humans to become resistant to the drugs; pathogens become resistant.

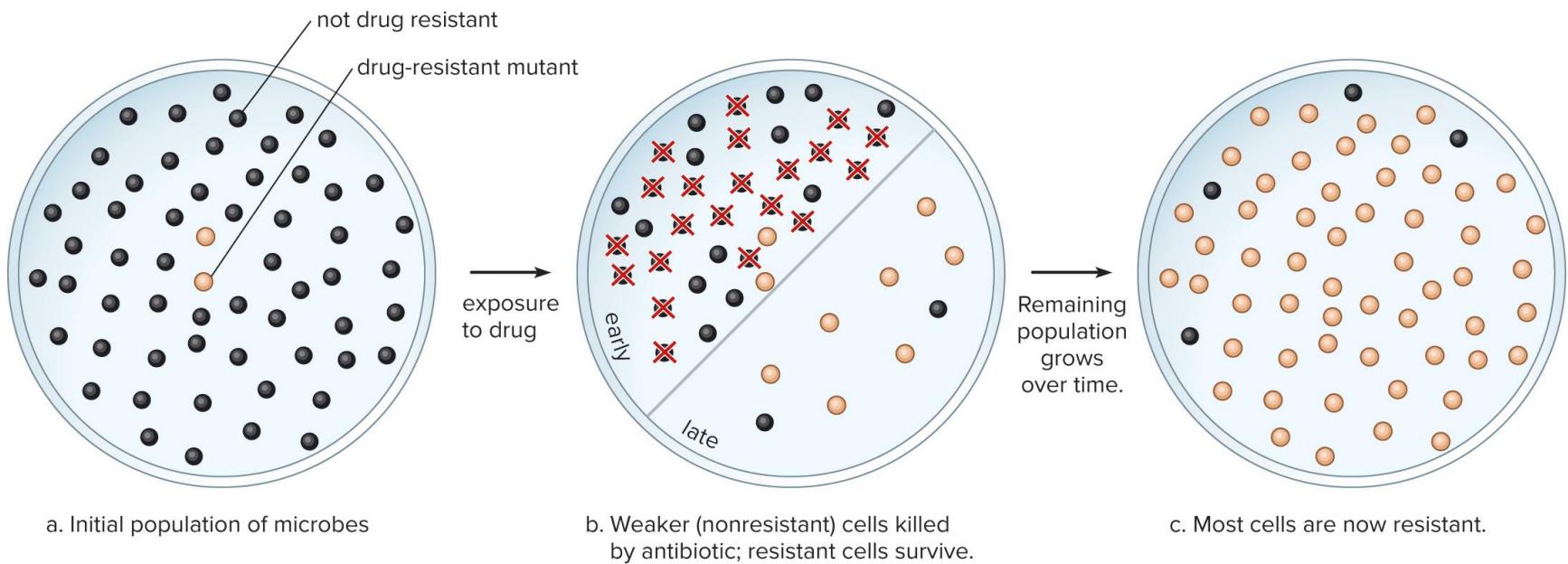
In any given population of pathogens, there are some organisms that are naturally resistant to the drug.

- They have acquired this resistance through mutations or interactions with other organisms.

The drug kills susceptible ones but leaves naturally resistant ones to multiply.

- The new population is then resistant to the drug.

# Development of Antibiotic Resistance (Figure 8.14)



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## 8.4 Antibiotic Resistance <sup>3</sup>

### Antibiotic resistance, continued.

- Tuberculosis, malaria, gonorrhea, *Staphylococcus aureus*, and enterococci (or group D *Streptococcus*) are a few of the organisms that have developed antibiotic resistance.
- More and more organisms are becoming multidrug-resistant, leaving health-care facilities with few choices for treating infections.

## 8.4 Antibiotic Resistance <sup>4</sup>

Prevention of antibiotic resistance:

- Take all of the antibiotics prescribed as directed; do not skip doses or discontinue treatment when you feel better.
- Do not take antibiotics for viral infections, such as colds.
- Do not save unused antibiotics or take antibiotics prescribed for a different infection.

Each year in the United States, at least 2.8 million people become infected with antibiotic-resistant bacteria, resulting in 35,000 deaths.

# Multidrug-Resistant Organisms

Multidrug-resistant organisms (MDRO).

**XDR TB—extensively drug-resistant tuberculosis.**

- Resistant to almost all the drugs used to treat TB, including the first-line antibiotics (older and cheaper ones), as well as the second-line antibiotics (newer and more expensive drugs).

**Methicillin-resistant *Staphylococcus aureus* (MRSA).**

- Resistant to methicillin and other antibiotics.
- Causes “staph” infections.
- In 1974, only 2% of staph infections were caused by MRSA, but by 2004 the number had risen to 63%.

# Check Your Progress 8.4

Explain how bacteria become resistant to an antibiotic.

Describe the correct procedure for taking antibiotics.

Explain what is meant when an organism is classified as an MDRO and give an example.