LECTURE PRESENTATIONS
For CAMPBELL BIOLOGY, NINTH EDITION

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Chapter 19

Viruses

Lectures by
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Overview: A Borrowed Life

- Viruses called bacteriophages can infect and set in motion a genetic takeover of bacteria, such as *Escherichia coli*
- Viruses lead “a kind of borrowed life” between life-forms and chemicals
- The origins of molecular biology lie in early studies of viruses that infect bacteria

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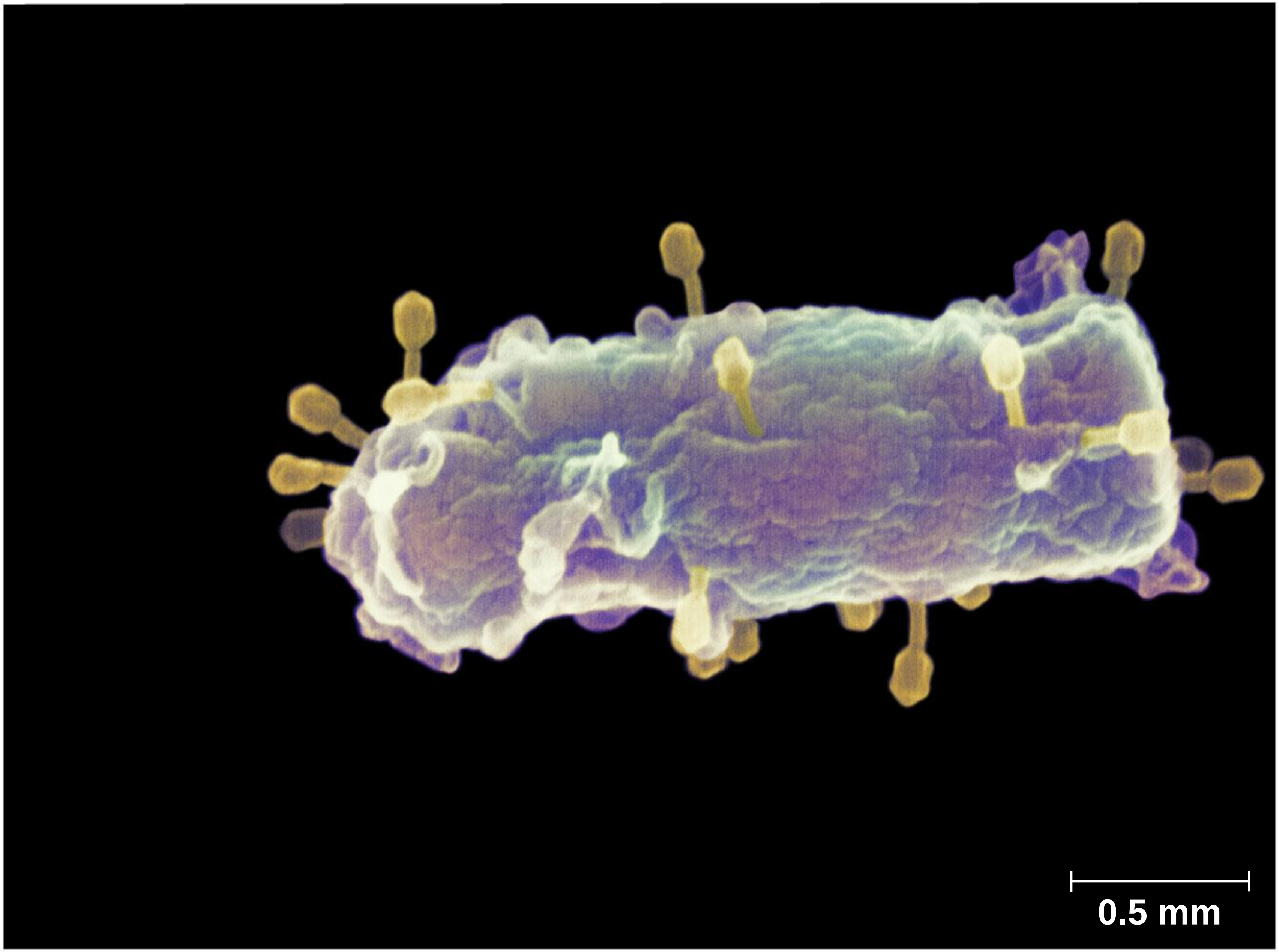
Figure 19.1



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Concept 19.1: A virus consists of a nucleic acid surrounded by a protein coat

- Viruses were detected indirectly long before they were actually seen

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The Discovery of Viruses: *Scientific Inquiry*

- Tobacco mosaic disease stunts growth of tobacco plants and gives their leaves a mosaic coloration
- In the late 1800s, researchers hypothesized that a particle smaller than bacteria caused the disease
- In 1935, Wendell Stanley confirmed this hypothesis by crystallizing the infectious particle, now known as tobacco mosaic virus (TMV)

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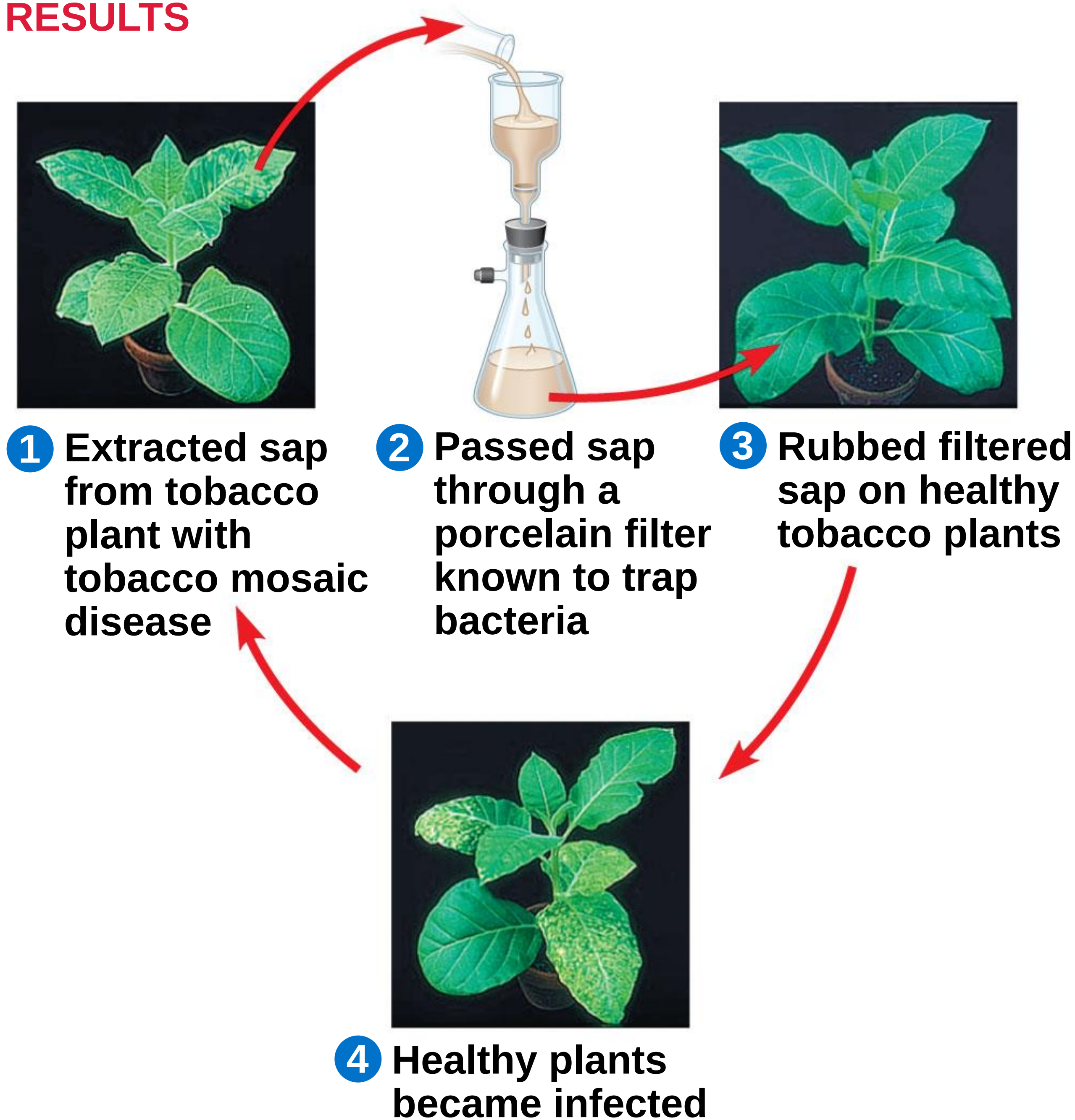
Figure 19.2

RESULTS



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Structure of Viruses

- Viruses are not cells
- A **virus** is a very small infectious particle consisting of nucleic acid enclosed in a protein coat and, in some cases, a membranous envelope

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Viral Genomes

- Viral genomes may consist of either
  - Double- or single-stranded DNA, or
  - Double- or single-stranded RNA
- Depending on its type of nucleic acid, a virus is called a DNA virus or an RNA virus

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Capsids and Envelopes

- A **capsid** is the protein shell that encloses the viral genome
- Capsids are built from protein subunits called *capsomeres*
- A capsid can have various structures

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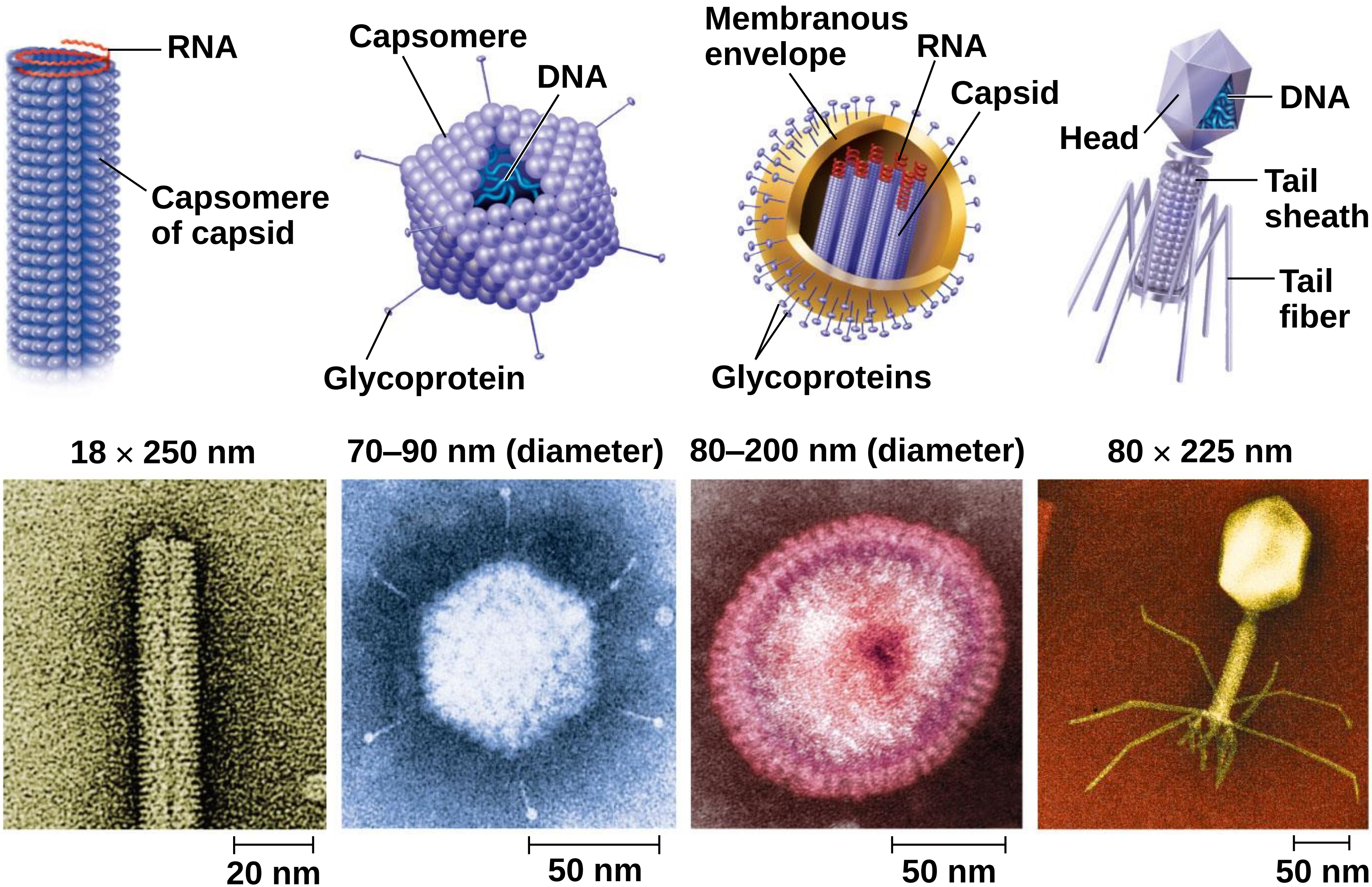
Figure 19.3



(a) Tobacco mosaic virus (b) Adenoviruses (c) Influenza viruses (d) Bacteriophage T4

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- Some viruses have membranous envelopes that help them infect hosts
- These **viral envelopes** surround the capsids of influenza viruses and many other viruses found in animals
- Viral envelopes, which are derived from the host cell’s membrane, contain a combination of viral and host cell molecules

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- **Bacteriophages**, also called **phages**, are viruses that infect bacteria
- They have the most complex capsids found among viruses
- Phages have an elongated capsid head that encloses their DNA
- A protein tail piece attaches the phage to the host and injects the phage DNA inside

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Concept 19.2: Viruses replicate only in host cells

- Viruses are obligate intracellular parasites, which means they can replicate only within a host cell
- Each virus has a **host range**, a limited number of host cells that it can infect

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General Features of Viral Replicative Cycles

- Once a viral genome has entered a cell, the cell begins to manufacture viral proteins
- The virus makes use of host enzymes, ribosomes, tRNAs, amino acids, ATP, and other molecules
- Viral nucleic acid molecules and capsomeres spontaneously self-assemble into new viruses

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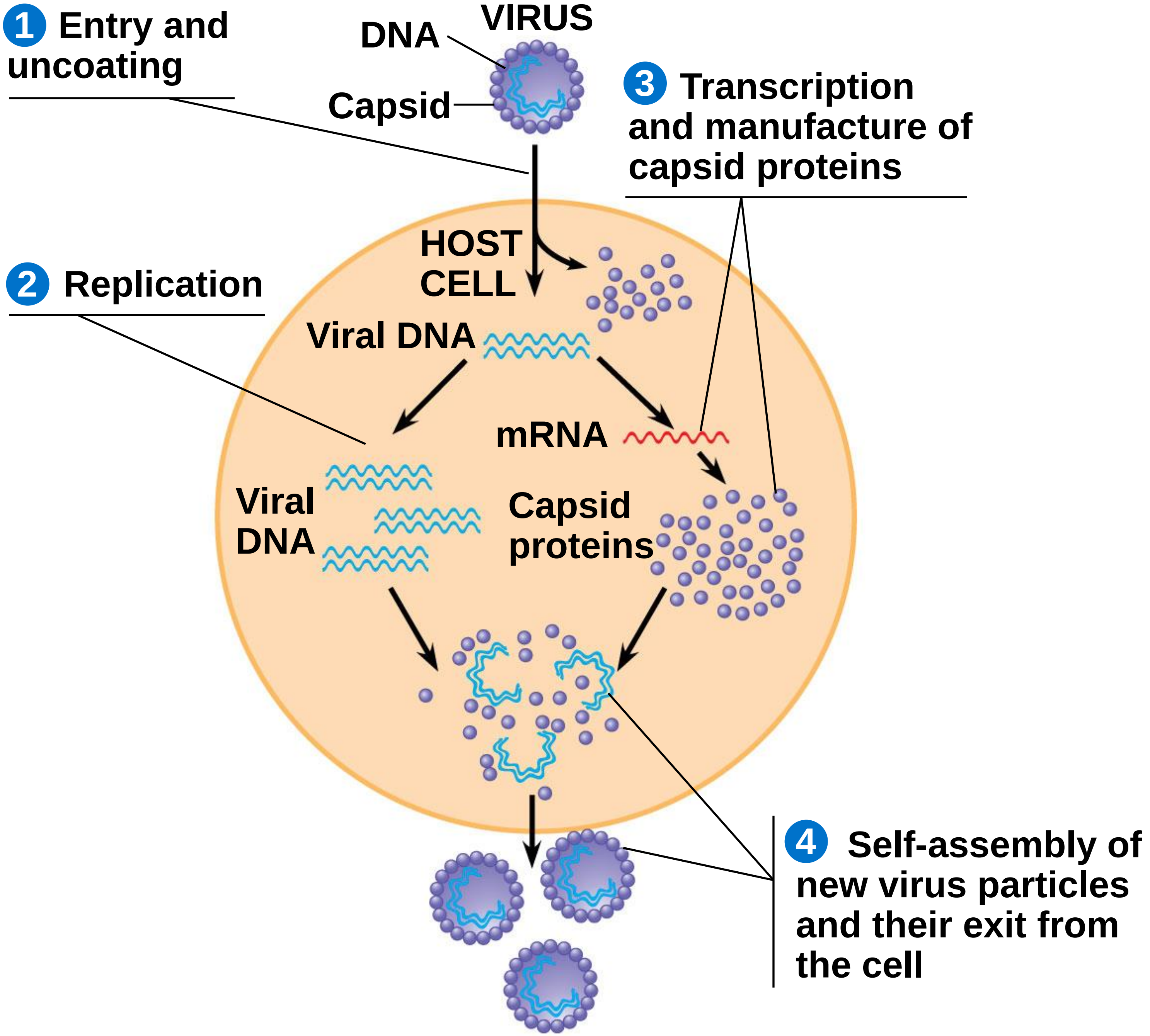
Figure 19.4



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Replicative Cycles of Phages

- Phages are the best understood of all viruses
- Phages have two reproductive mechanisms: the lytic cycle and the lysogenic cycle

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The Lytic Cycle

- The **lytic cycle** is a phage replicative cycle that culminates in the death of the host cell
- The lytic cycle produces new phages and lyses (breaks open) the host’s cell wall, releasing the progeny viruses
- A phage that reproduces only by the lytic cycle is called a **virulent phage**
- Bacteria have defenses against phages, including **restriction enzymes** that recognize and cut up certain phage DNA

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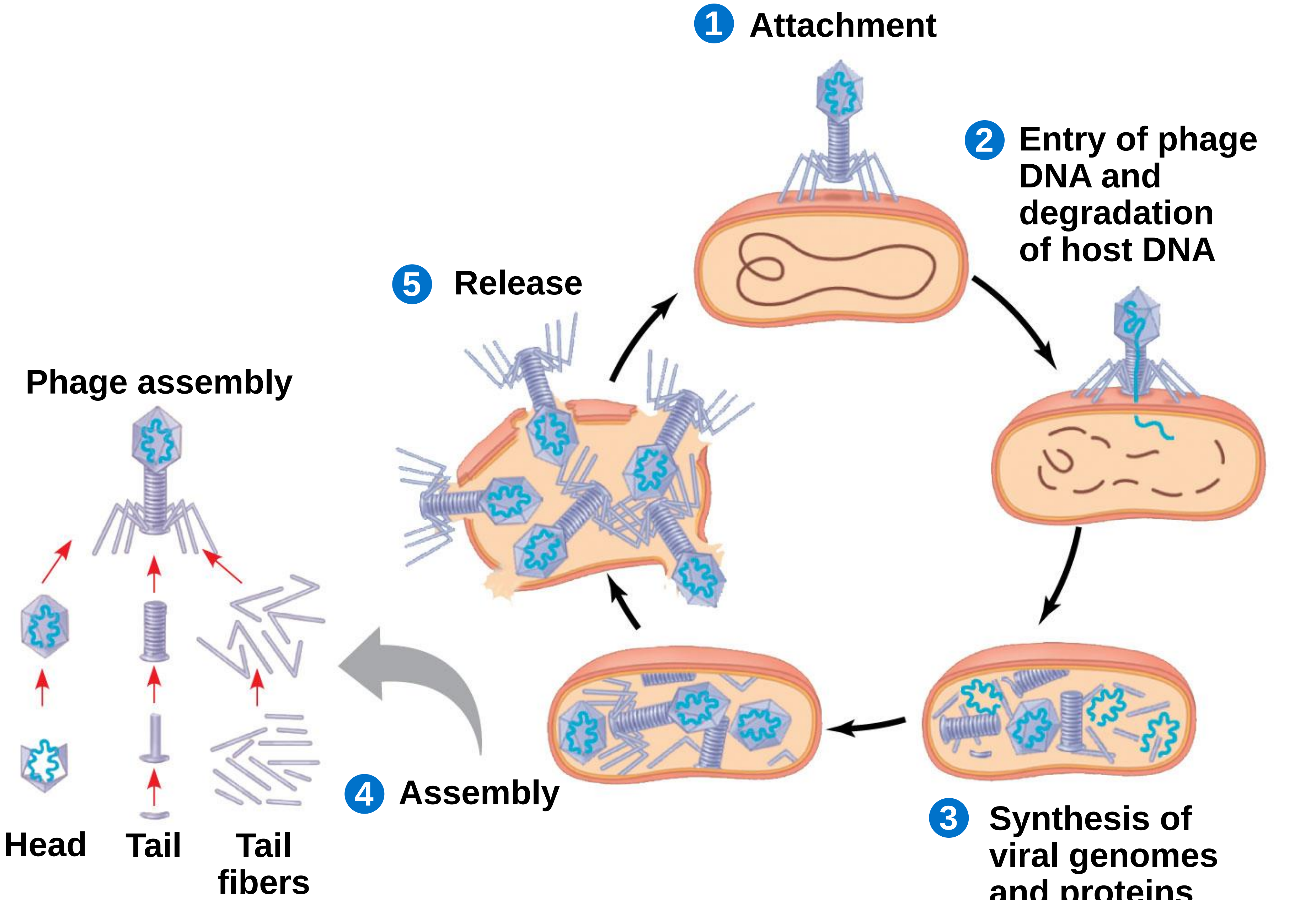
Figure 19.5-5



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The Lysogenic Cycle

- The **lysogenic cycle** replicates the phage genome without destroying the host
- The viral DNA molecule is incorporated into the host cell’s chromosome
- This integrated viral DNA is known as a **prophage**
- Every time the host divides, it copies the phage DNA and passes the copies to daughter cells

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- An environmental signal can trigger the virus genome to exit the bacterial chromosome and switch to the lytic mode
- Phages that use both the lytic and lysogenic cycles are called **temperate phages**

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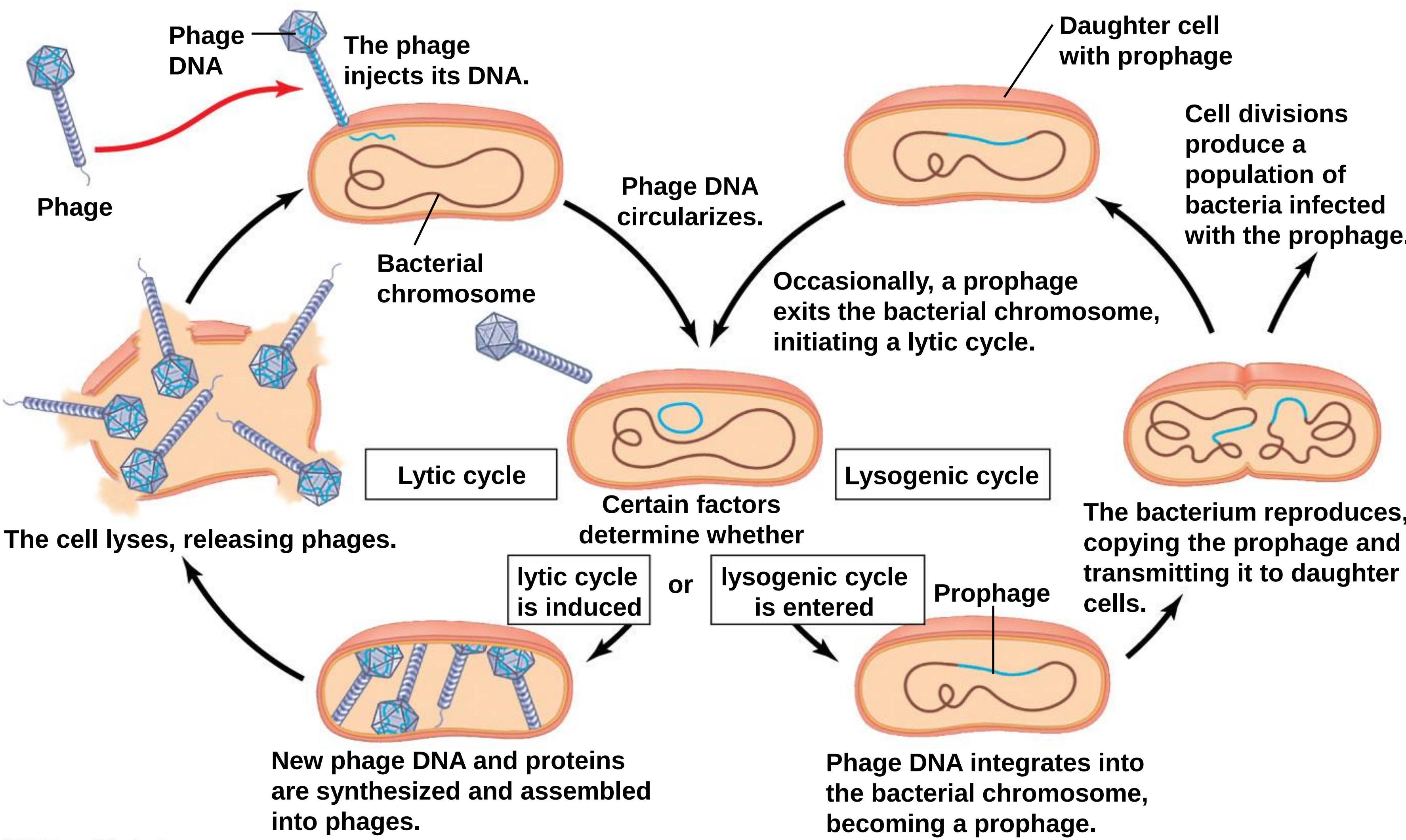
Figure 19.6



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Replicative Cycles of Animal Viruses

- There are two key variables used to classify viruses that infect animals
  - DNA or RNA?
  - Single-stranded or double-stranded?

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Table 19.1

Table 19.1 Classes of Animal Viruses

Class/Family	Envelope	Examples That Cause Human Diseases
I. Double-Stranded DNA (dsDNA)		
Adenovirus (see Figure 19.3b)	No	Respiratory viruses; tumor-causing viruses
Papovavirus	No	Papillomavirus (warts, cervical cancer); polyomavirus (tumors)
Herpesvirus	Yes	Herpes simplex I and II (cold sores, genital sores); varicella zoster (shingles, chicken pox); Epstein-Barr virus (mononucleosis, Burkitt's lymphoma)
Poxvirus	Yes	Smallpox virus; cowpox virus
II. Single-Stranded DNA (ssDNA)		
Parvovirus	No	B19 parvovirus (mild rash)
III. Double-Stranded RNA (dsRNA)		
Reovirus	No	Rotavirus (diarrhea); Colorado tick fever virus
IV. Single-Stranded RNA (ssRNA); Serves as mRNA		
Picornavirus	No	Rhinovirus (common cold); poliovirus; hepatitis A virus; other enteric (intestinal) viruses
Coronavirus	Yes	Severe acute respiratory syndrome (SARS)
Flavivirus	Yes	Yellow fever virus; West Nile virus; hepatitis C virus
Togavirus	Yes	Rubella virus; equine encephalitis viruses
V. ssRNA; Template for mRNA Synthesis		
Filovirus	Yes	Ebola virus (hemorrhagic fever)
Orthomyxovirus (see Figures 19.3c and 19.9a)	Yes	Influenza virus
Paramyxovirus	Yes	Measles virus; mumps virus
Rhabdovirus	Yes	Rabies virus
VI. ssRNA; Template for DNA Synthesis		
Retrovirus (see Figure 19.8)	Yes	Human immunodeficiency virus (HIV/AIDS); RNA tumor viruses (leukemia)

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Table 19.1a

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II. Single-Stranded DNA (ssDNA)		
Parvovirus	No	B19 parvovirus (mild rash)
III. Double-Stranded RNA (dsRNA)		
Reovirus	No	Rotavirus (diarrhea); Colorado tick fever virus

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Table 19.1b

Table 19.1 Classes of Animal Viruses (continued)

Class/Family	Envelope	Examples That Cause Human Diseases
IV. Single-Stranded RNA (ssRNA); Serves as mRNA		
Picornavirus	No	Rhinovirus (common cold); poliovirus; hepatitis A virus; other enteric (intestinal) viruses
Coronavirus	Yes	Severe acute respiratory syndrome (SARS)
Flavivirus	Yes	Yellow fever virus; West Nile virus; hepatitis C virus
Togavirus	Yes	Rubella virus; equine encephalitis viruses
V. ssRNA; Template for mRNA Synthesis		
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VI. ssRNA; Template for DNA Synthesis		
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Viral Envelopes

- Many viruses that infect animals have a membranous envelope
- Viral glycoproteins on the envelope bind to specific receptor molecules on the surface of a host cell
- Some viral envelopes are formed from the host cell’s plasma membrane as the viral capsids exit

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- Other viral membranes form from the host's nuclear envelope and are then replaced by an envelope made from Golgi apparatus membrane

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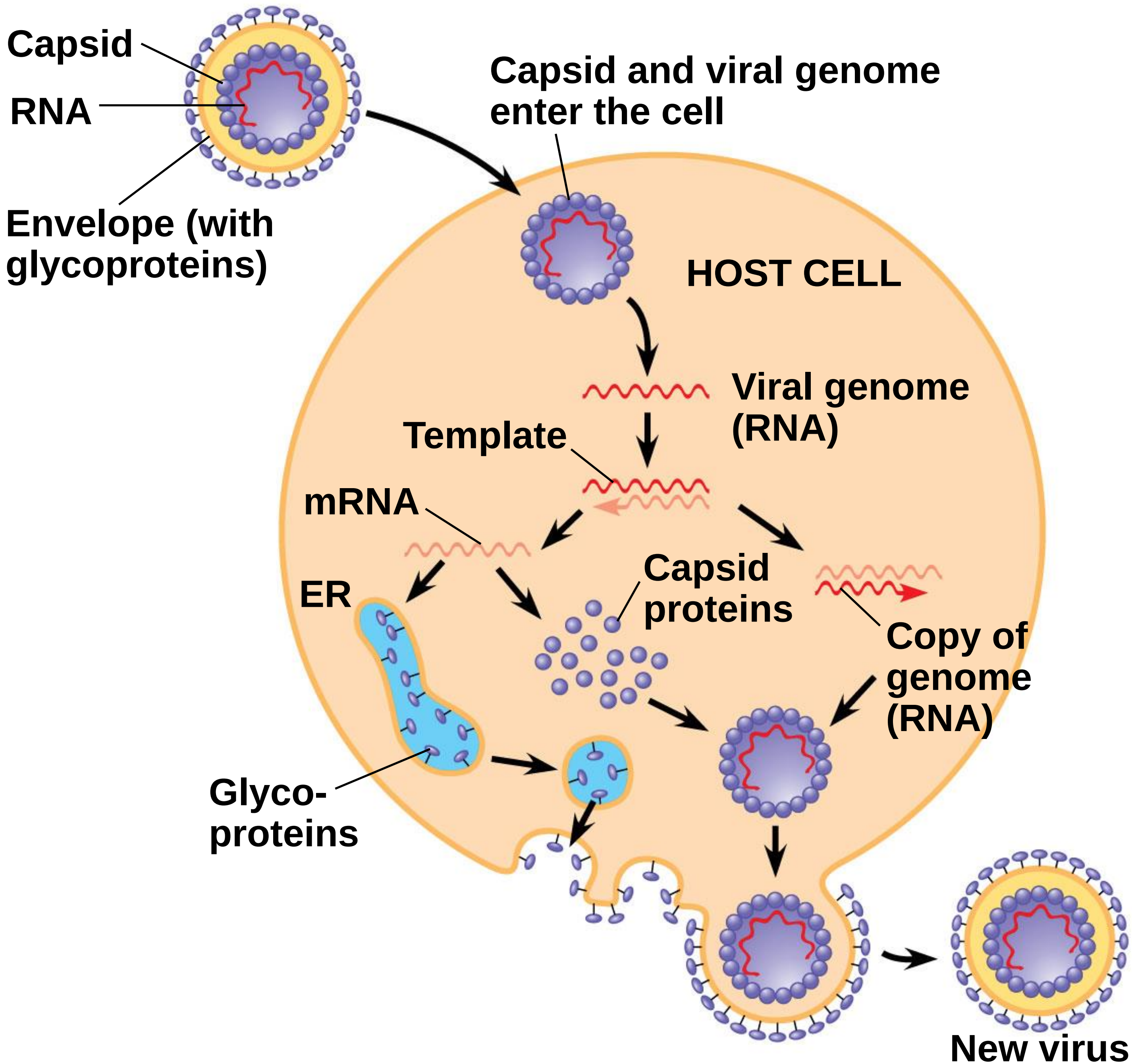
Figure 19.7



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RNA as Viral Genetic Material

- The broadest variety of RNA genomes is found in viruses that infect animals
- **Retroviruses** use **reverse transcriptase** to copy their RNA genome into DNA
- **HIV (human immunodeficiency virus)** is the retrovirus that causes **AIDS (acquired immunodeficiency syndrome)**

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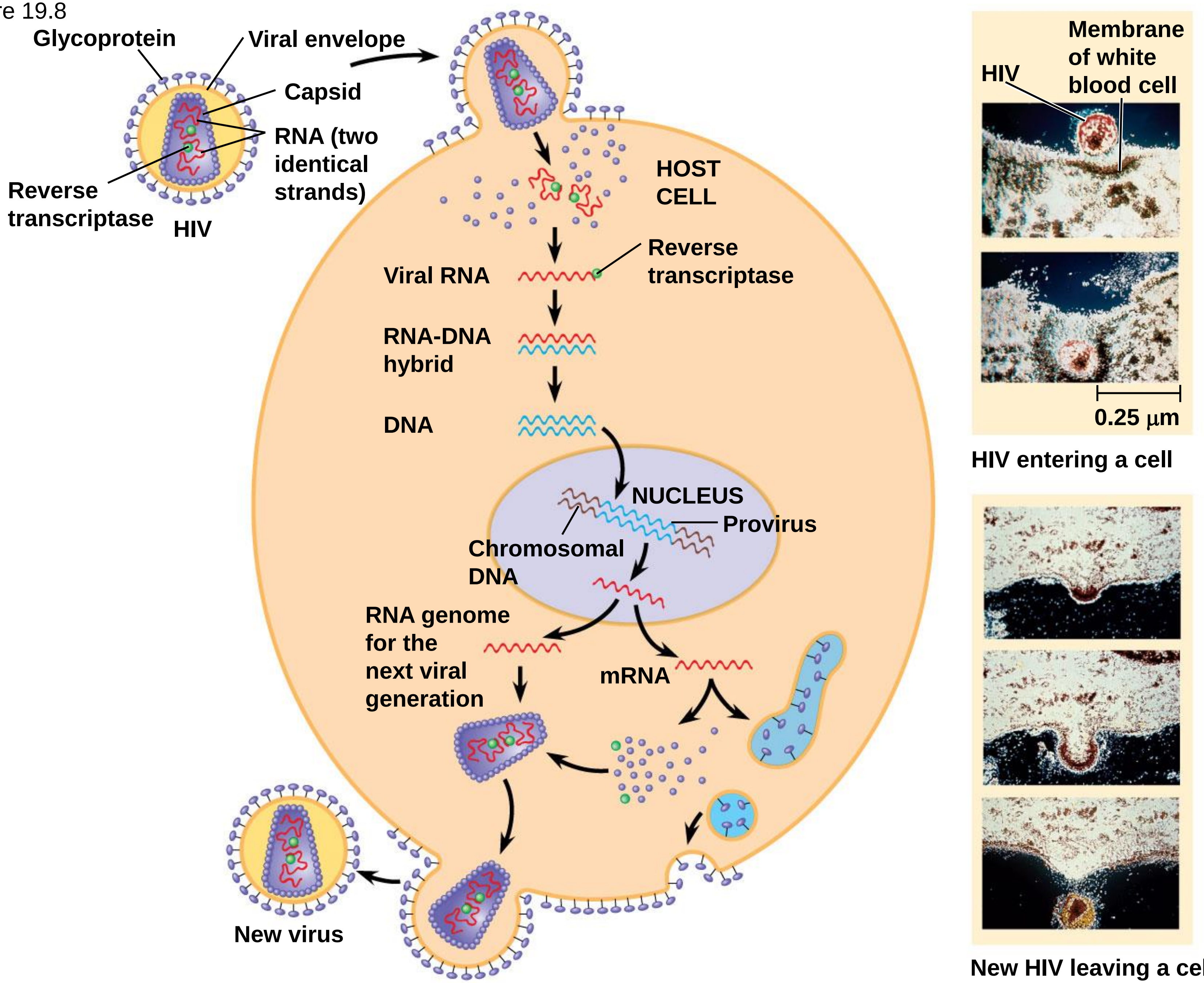
Figure 19.8



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- The viral DNA that is integrated into the host genome is called a **provirus**
- Unlike a prophage, a provirus remains a permanent resident of the host cell
- The host's RNA polymerase transcribes the proviral DNA into RNA molecules
- The RNA molecules function both as mRNA for synthesis of viral proteins and as genomes for new Avirus particles released from the cell

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Evolution of Viruses

- Viruses do not fit our definition of living organisms
- Since viruses can replicate only within cells, they probably evolved as bits of cellular nucleic acid
- Candidates for the source of viral genomes are plasmids, circular DNA in bacteria and yeasts, and transposons, small mobile DNA segments
- Plasmids, transposons, and viruses are all mobile genetic elements

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- Mimivirus, a double-stranded DNA virus, the largest virus yet discovered, is the size of a small bacterium
- There is controversy about whether this virus evolved before or after cells

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Concept 19.3: Viruses, viroids, and prions are formidable pathogens in animals and plants

- Diseases caused by viral infections affect humans, agricultural crops, and livestock worldwide
- Smaller, less complex entities called viroids and prions also cause disease in plants and animals, respectively

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Viral Diseases in Animals

- Viruses may damage or kill cells by causing the release of hydrolytic enzymes from lysosomes
- Some viruses cause infected cells to produce toxins that lead to disease symptoms
- Others have molecular components such as envelope proteins that are toxic

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- **Vaccines** are harmless derivatives of pathogenic microbes that stimulate the immune system to mount defenses against the harmful pathogen
- Vaccines can prevent certain viral illnesses
- Viral infections cannot be treated by antibiotics
- Antiviral drugs can help to treat, though not cure, viral infections

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Emerging Viruses

- Emerging viruses are those that suddenly become apparent
- Recently, a general outbreak (**epidemic**) of a flu-like illness appeared in Mexico and the United States, caused by an influenza virus named H1N1
- Flu epidemics are caused by new strains of influenza virus to which people have little immunity

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- Viral diseases in a small isolated population can emerge and become global
- New viral diseases can emerge when viruses spread from animals to humans
- Viral strains that jump species can exchange genetic information with other viruses to which humans have no immunity

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- These strains can cause **pandemics**, global epidemics
- The 2009 flu pandemic was likely passed to humans from pigs; for this reason it was originally called the “swine flu”

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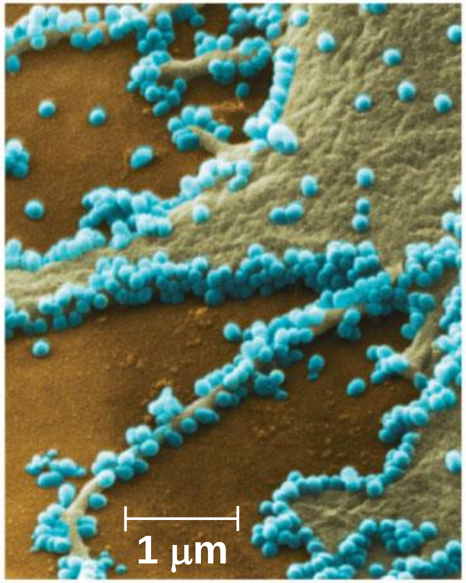
Figure 19.9



(a) 2009 pandemic H1N1 influenza A virus

(b) 2009 pandemic screening

(c) 1918 flu pandemic

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Viral Diseases in Plants

- More than 2,000 types of viral diseases of plants are known and cause spots on leaves and fruits, stunted growth, and damaged flowers or roots
- Most plant viruses have an RNA genome

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Figure 19.10

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- Plant viruses spread disease in two major modes
  - Horizontal transmission, entering through damaged cell walls
  - Vertical transmission, inheriting the virus from a parent

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Viroids and Prions: The Simplest Infectious Agents

- **Viroids** are small circular RNA molecules that infect plants and disrupt their growth
- **Prions** are slow-acting, virtually indestructible infectious proteins that cause brain diseases in mammals
- Prions propagate by converting normal proteins into the prion version
- Scrapie in sheep, mad cow disease, and Creutzfeldt-Jakob disease in humans are all caused by prions

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Figure 19.11

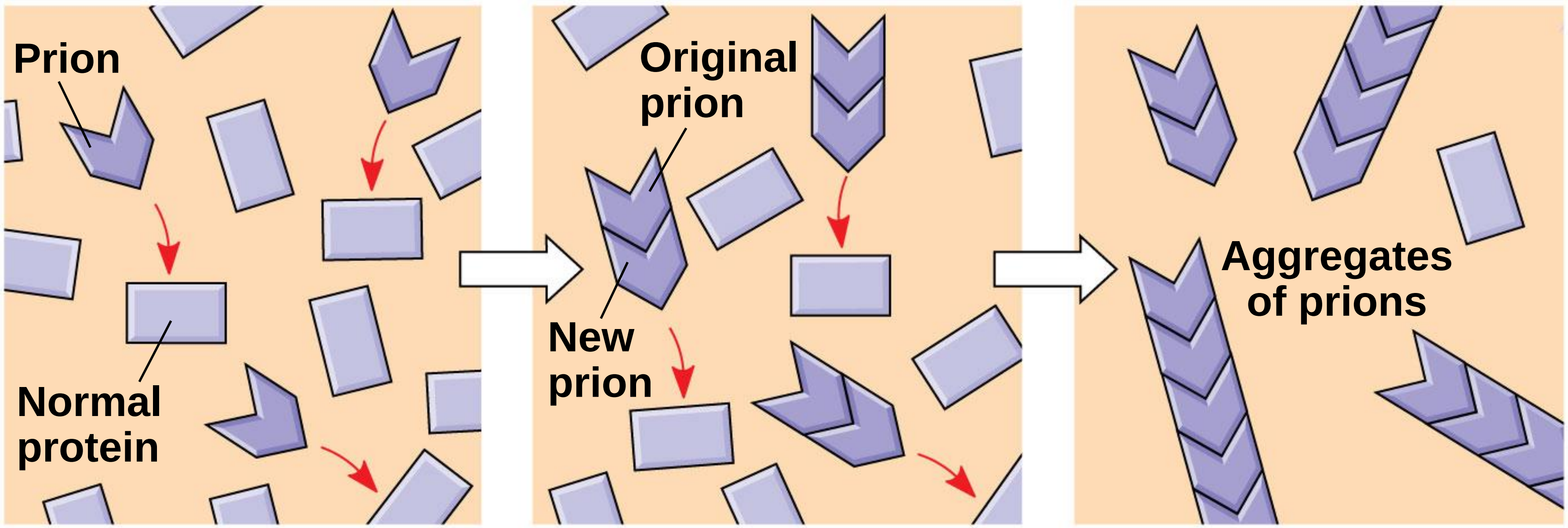

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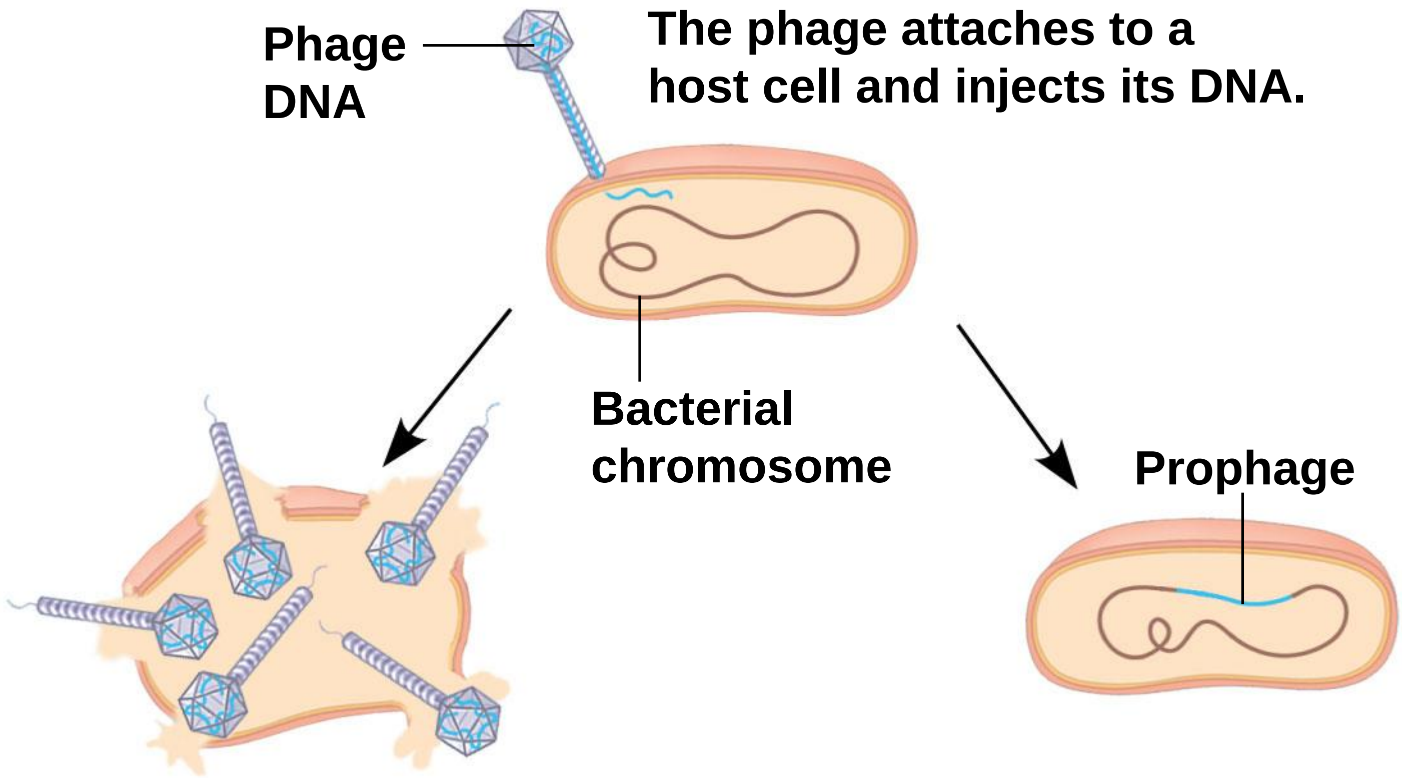
Figure 19.UN01



Lytic cycle
- Virulent or temperate phage
- Destruction of host DNA
- Production of new phages
- Lysis of host cell causes release of progeny phages

Lysogenic cycle
- Temperate phage only
- Genome integrates into bacterial chromosome as prophage, which (1) is replicated and passed on to daughter cells and (2) can be induced to leave the chromosome and initiate a lytic cycle

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Figure 19.UN02

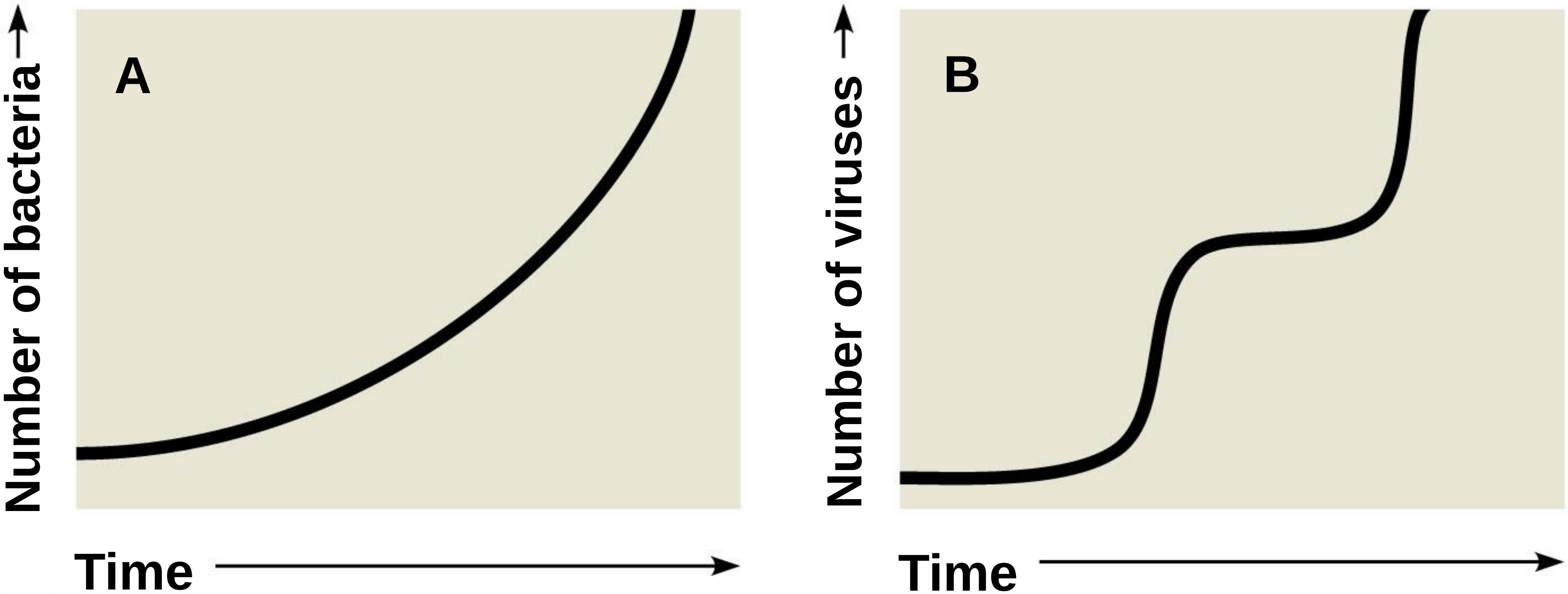

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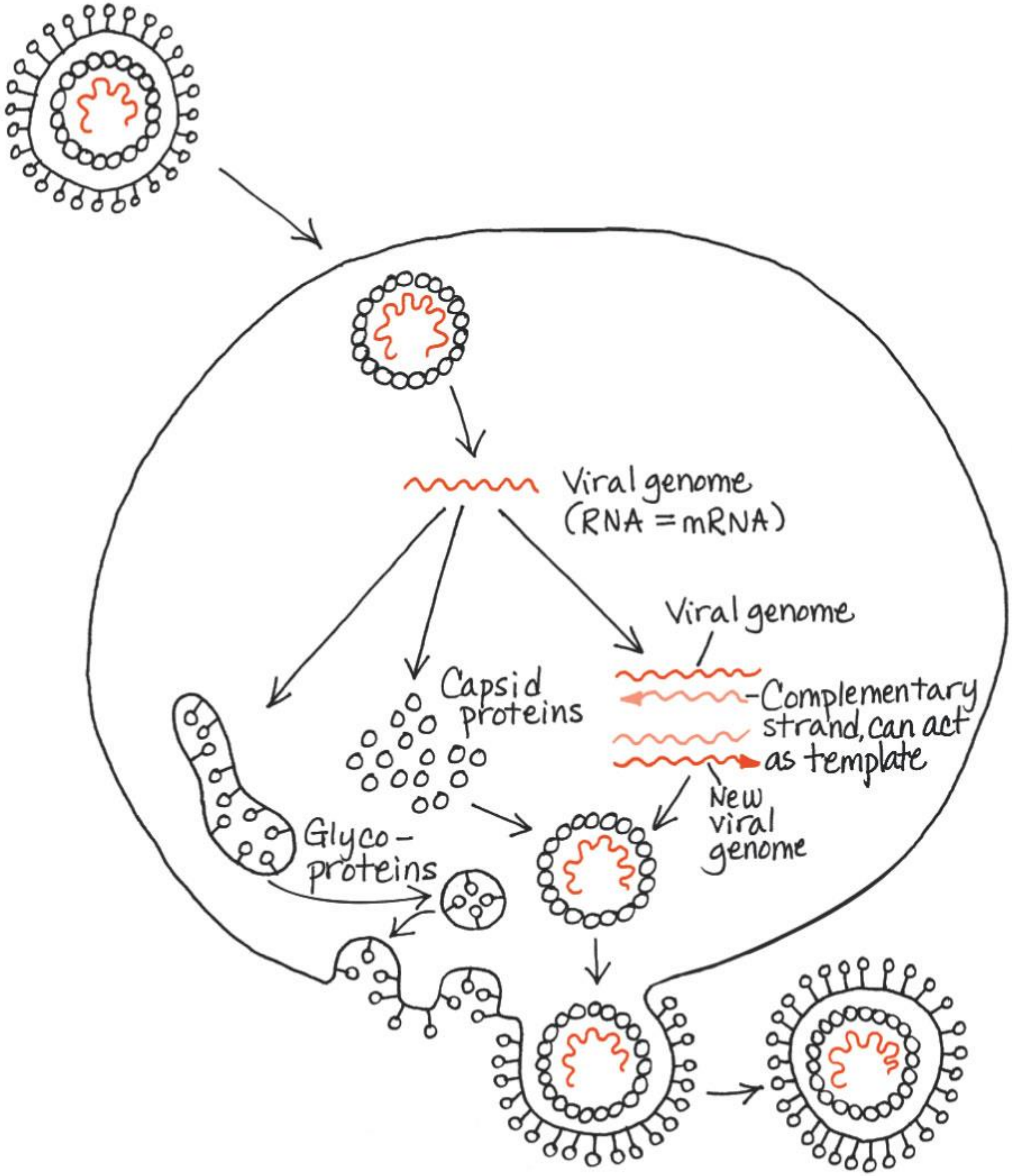
Figure 19.UN03



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BACTERIA 27.2: Rapid reproduction, mutation, and genetic recombination promote genetic diversity in prokaryotes

- Prokaryotes have considerable genetic variation
- Three factors contribute to this genetic diversity:
  - Rapid reproduction
  - Mutation
  - Genetic recombination

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Rapid Reproduction and Mutation

- Prokaryotes reproduce by binary fission, and offspring cells are generally identical
- Mutation rates during binary fission are low, but because of rapid reproduction, mutations can accumulate rapidly in a population
- High diversity from mutations allows for rapid evolution

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Genetic Recombination

- Genetic recombination, the combining of DNA from two sources, contributes to diversity
- Prokaryotic DNA from different individuals can be brought together by transformation, transduction, and conjugation
- Movement of genes among individuals from different species is called horizontal gene transfer

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Transformation and Transduction

- A prokaryotic cell can take up and incorporate foreign DNA from the surrounding environment in a process called **transformation**
- **Transduction** is the movement of genes between bacteria by bacteriophages (viruses that infect bacteria)

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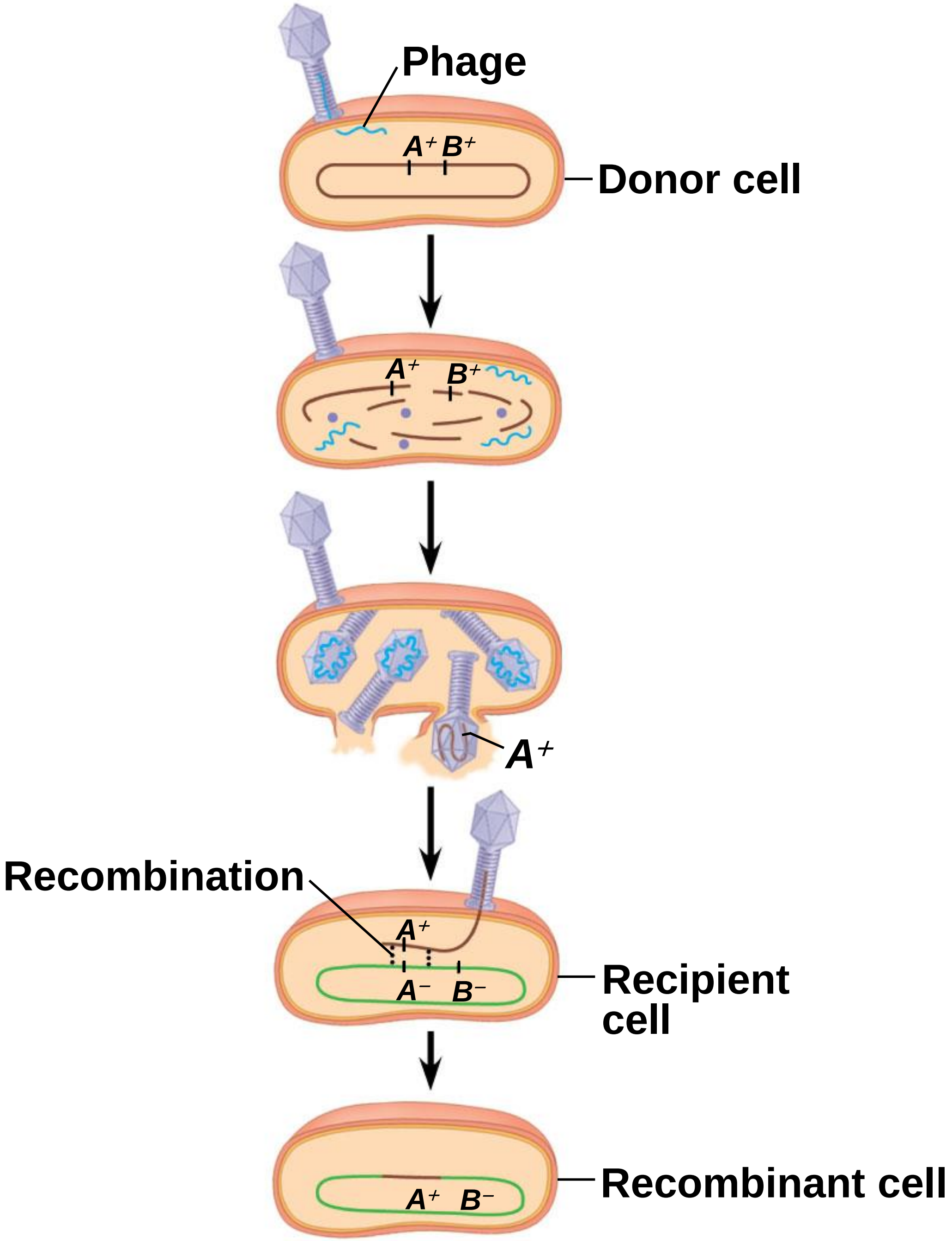
Figure 27.11-4



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Conjugation and Plasmids

- **Conjugation** is the process where genetic material is transferred between prokaryotic cells
- In bacteria, the DNA transfer is one way
- A donor cell attaches to a recipient by a pilus, pulls it closer, and transfers DNA
- A piece of DNA called the **F factor** is required for the production of pili

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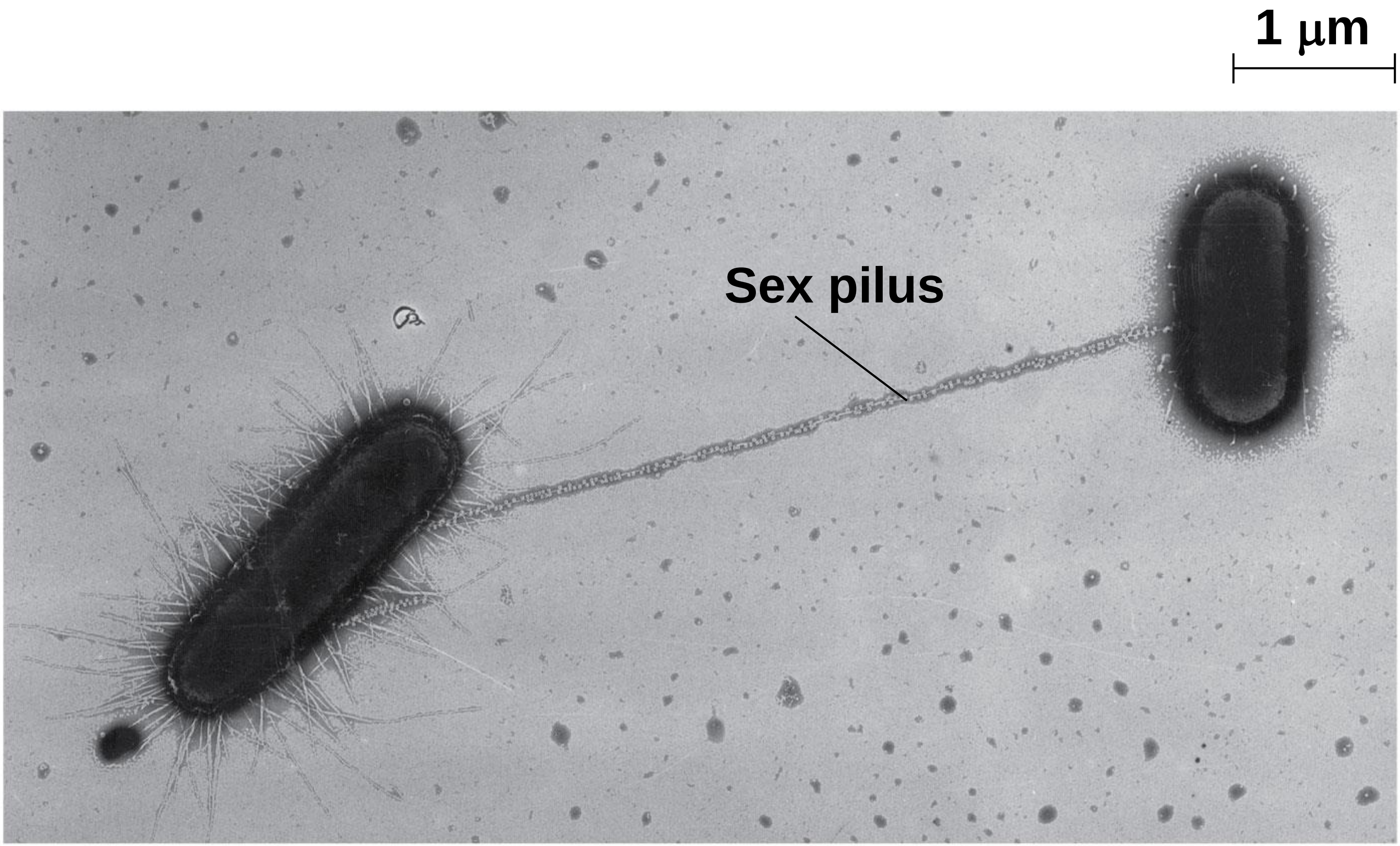
Figure 27.12



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The F Factor as a Plasmid

- Cells containing the **F plasmid** function as DNA donors during conjugation
- Cells without the F factor function as DNA recipients during conjugation
- The F factor is transferable during conjugation

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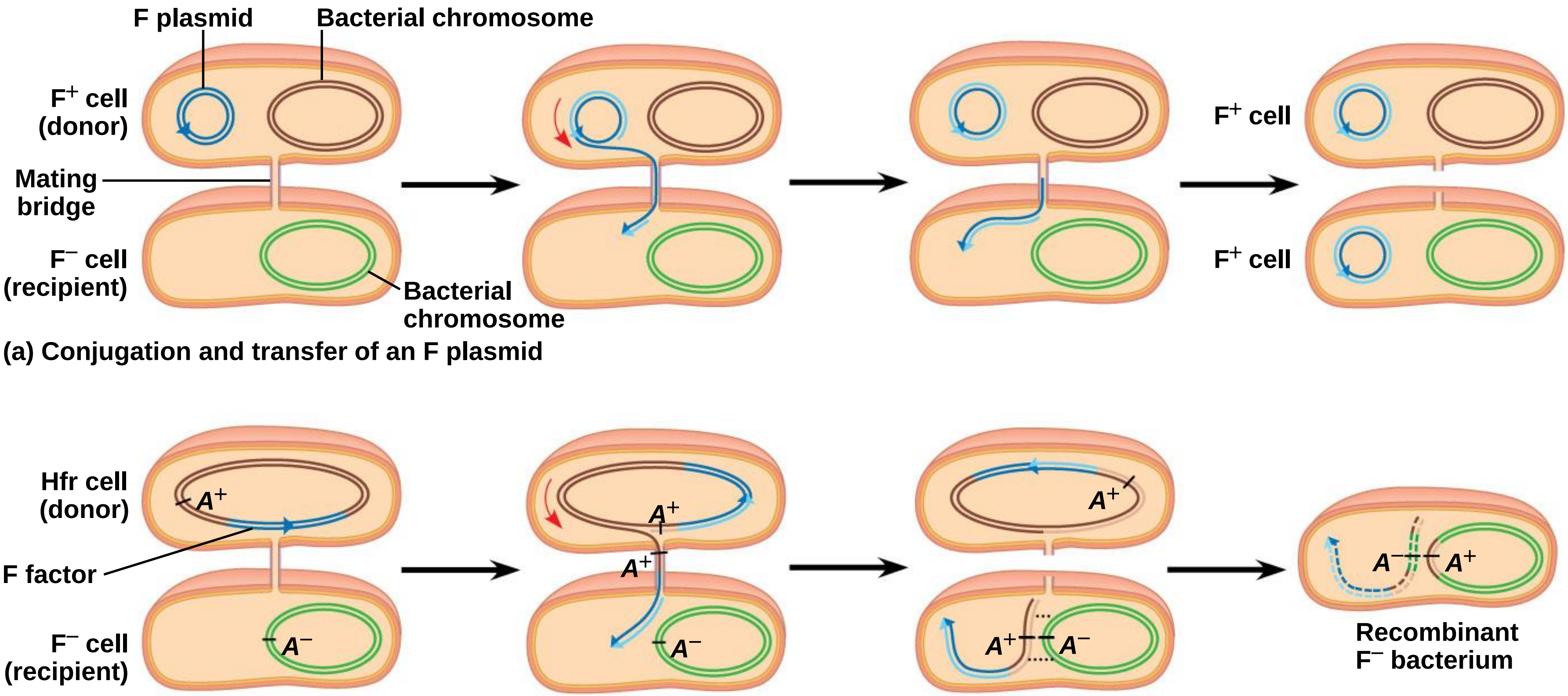
Figure 27.13



(a) Conjugation and transfer of an F plasmid

(b) Conjugation and transfer of part of an Hfr bacterial chromosome

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The F Factor in the Chromosome

- A cell with the F factor built into its chromosomes functions as a donor during conjugation
- The recipient becomes a recombinant bacterium, with DNA from two different cells

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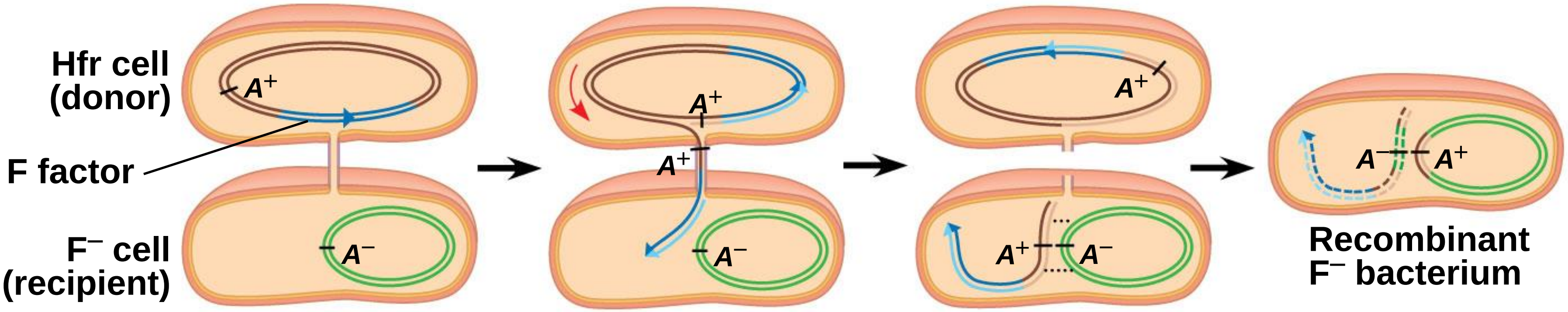
Figure 27.13b-3



(b) Conjugation and transfer of part of an Hfr bacterial chromosome

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R Plasmids and Antibiotic Resistance

- **R plasmids** carry genes for antibiotic resistance
- Antibiotics kill sensitive bacteria, but not bacteria with specific R plasmids
- Through natural selection, the fraction of bacteria with genes for resistance increases in a population exposed to antibiotics
- Antibiotic-resistant strains of bacteria are becoming more common

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