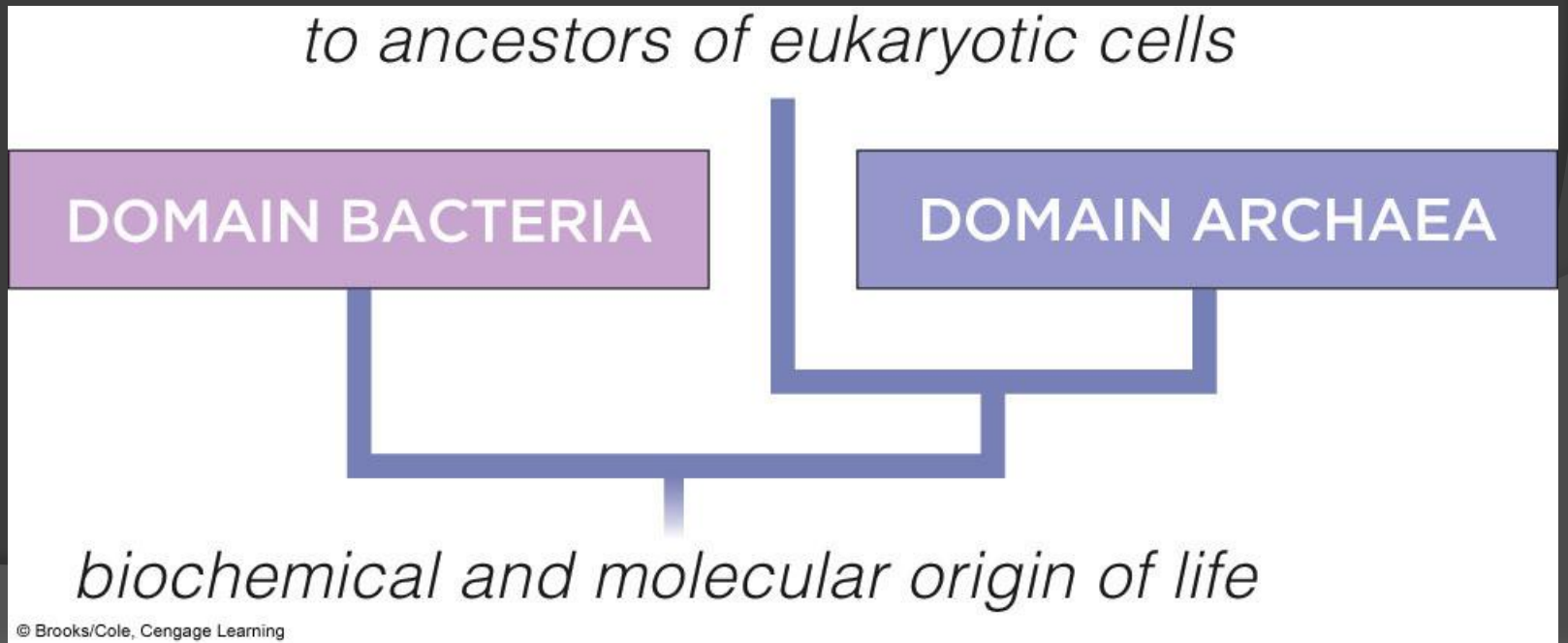
Chapter 21

VIRUSES AND PROKARYOTES

21.4 Prokaryotes—Enduring, Abundant, and Diverse

- **Prokaryotes**
  - Structurally simple cells that lack a nucleus
  - Evolved before eukaryotes



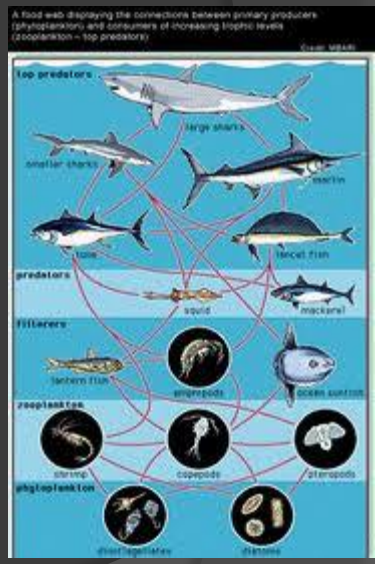
Abundance and Metabolic Diversity

- Prokaryotes are Earth's most abundant organisms
- Metabolic diversity contributes to their success
- All four forms of nutrition are used by prokaryotes

Mode of Nutrition	Carbon Source	Energy Source
Photoautotrophic	CO_2	Light
Chemoautotrophic	CO_2	Inorganic substances
Photoheterotrophic	Organic compounds	Light
Chemoheterotrophic	Organic compounds	Organic compounds

The Importance of Prokaryotes

- Decomposers – assist in breaking down dead organisms
- Producers – food chains are dependent on bacteria for producing food
  - 1 cyanobacterium (*Prochlorococcus*) is the most abundant photosynthetic organism – makes over ½ of food in the open ocean
- Nitrogen Fixers – converts nitrogen into a form plants use (N2 to NH3)
  - 90% of the nitrogen organisms use comes from fixation



Human Uses of Prokaryotes

- Production of Food – yogurt, cheese, vinegar
- Clean oil spills
- Remove human waste and poison from water
- Medicine – synthesize drugs – insulin, human growth hormone
- Digestion

Prokaryotic Cell Size and Shape

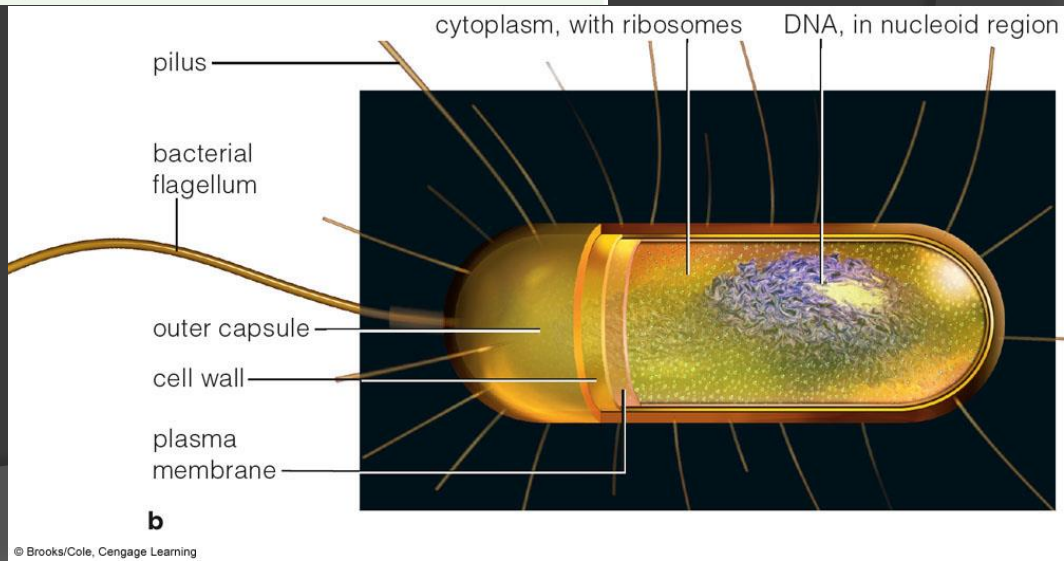
- Prokaryotic cells are much smaller than eukaryotic cells (about the size of mitochondria)

- Prokaryotes have three typical shapes:

Prokaryotic Cell Characteristics

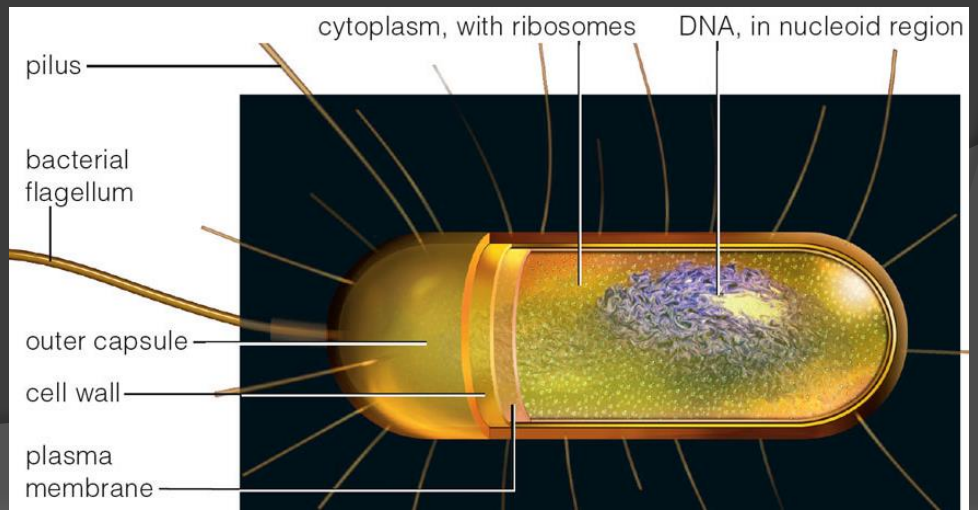
Table 21.4 Prokaryotic Cell Characteristics

1. No nucleus; chromosome in nucleoid
2. Generally a single chromosome (a circular DNA molecule); many species also contain plasmids
3. Cell wall present in most species
4. Ribosomes distributed in the cytoplasm



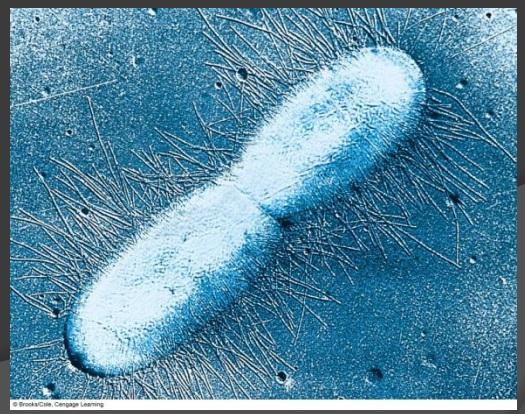
Prokaryotic Cell Characteristics

- Prokaryotic structure
  - **Nucleoid** region contains a single, circular chromosome
  - **Cell wall** surrounds the plasma membrane, with a slime layer (**capsule**) outside the cell wall
  - **Flagella** rotate like propellers
  - **Pili** extend from the cell surface for adhesion or motion

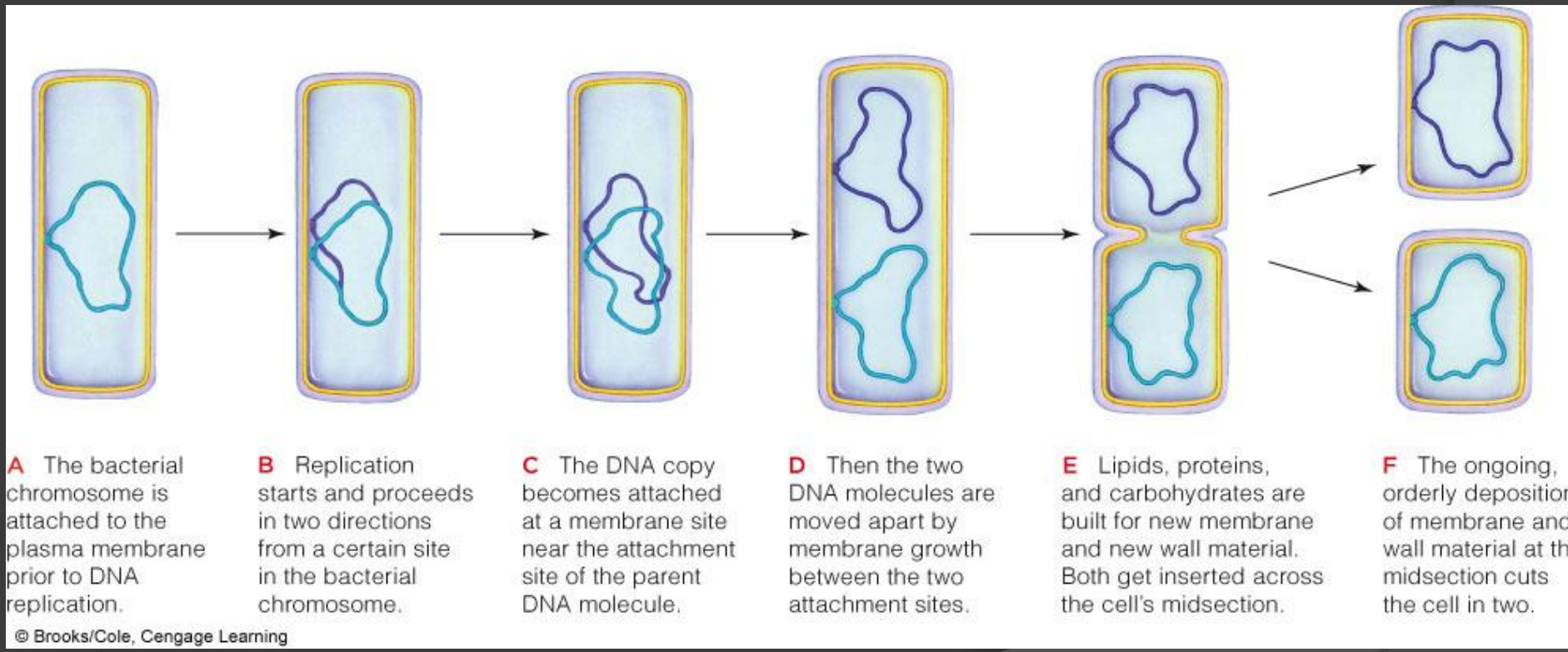


Prokaryotic Reproduction

- **Prokaryotic chromosome**
  - A circular, double-stranded DNA molecule
- **Prokaryotic fission (binary fission)**
  - DNA replicates; parent cell divides in two



Prokaryotic Fission



A The bacterial chromosome is attached to the plasma membrane prior to DNA replication.

B Replication starts and proceeds in two directions from a certain site in the bacterial chromosome.

C The DNA copy becomes attached at a membrane site near the attachment site of the parent DNA molecule.

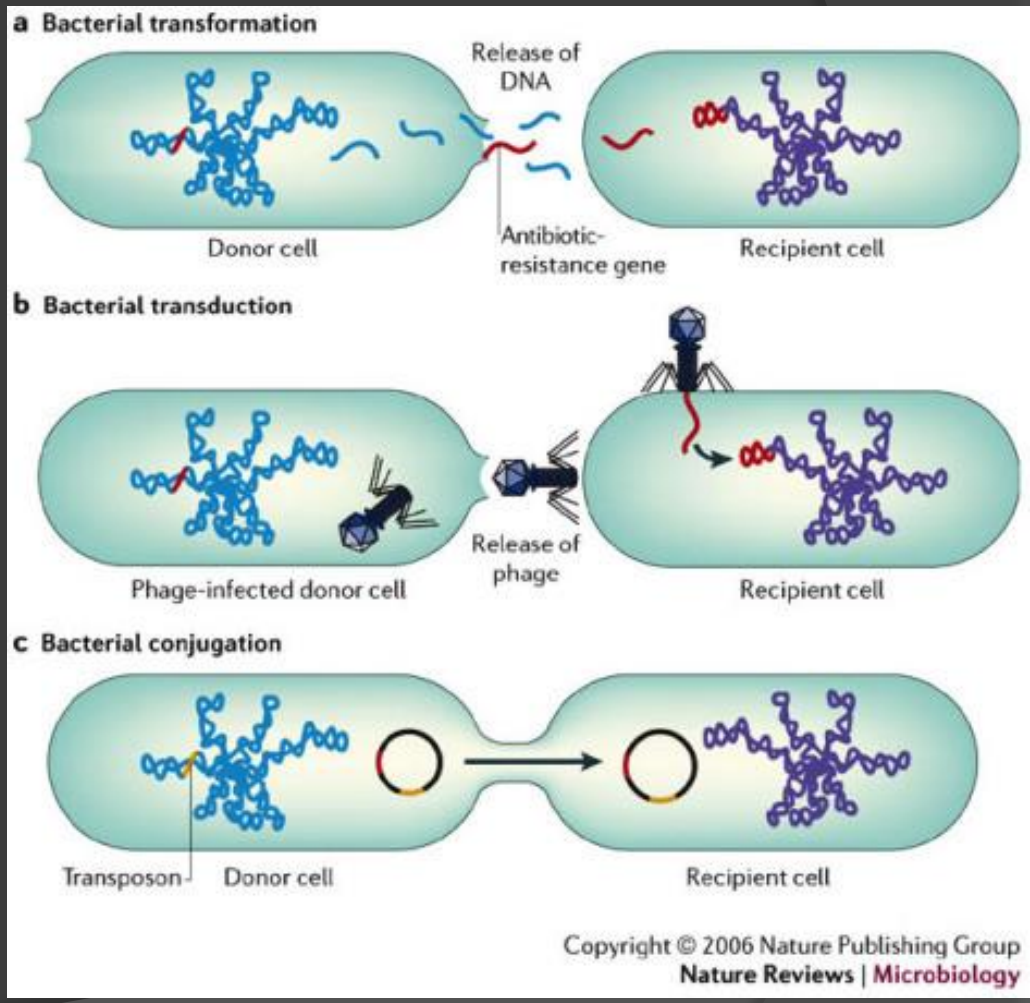
D Then the two DNA molecules are moved apart by membrane growth between the two attachment sites.

E Lipids, proteins, and carbohydrates are built for new membrane and new wall material. Both get inserted across the cell's midsection.

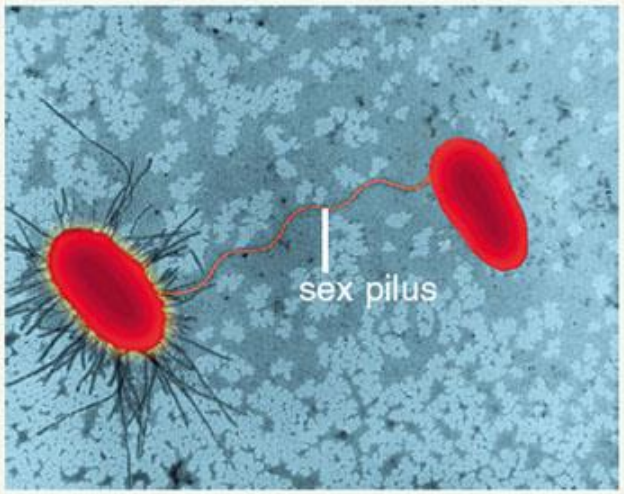
F The ongoing, orderly deposition of membrane and wall material at the midsection cuts the cell in two.

Horizontal Gene Transfers

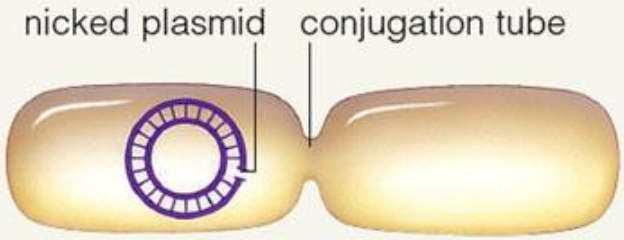
- **Transformation**
  - Prokaryotic genes acquired from the environment
- **Transduction**
  - Transfer of prokaryotic genes via bacteriophages
- **Conjugation**
  - Transfer of a **plasmid** (non-chromosomal DNA) between prokaryotic cells via a sex pilus
  - Conjugation & transduction



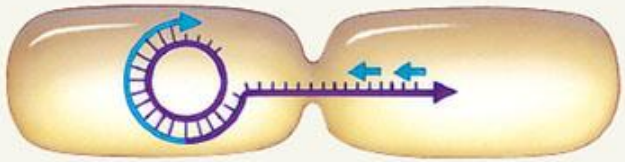
Conjugation



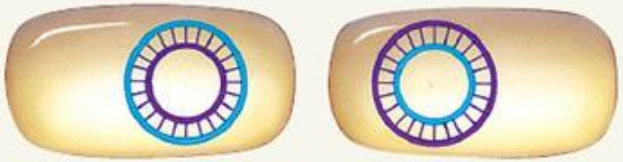
A Conjugation in *E. coli* begins when a cell with a specific type of plasmid extends a sex pilus to another *E. coli* cell that lacks this plasmid. The pilus attaches the cells to one another. When it shortens, the cells are drawn together.



B A conjugation tube forms, connecting the cytoplasm of the cells. An enzyme nicks the plasmid in the donor cell.



C As a single strand of plasmid DNA moves into the recipient, each cell makes a complimentary DNA strand.



D The cells separate and the plasmid resumes its circular shape.

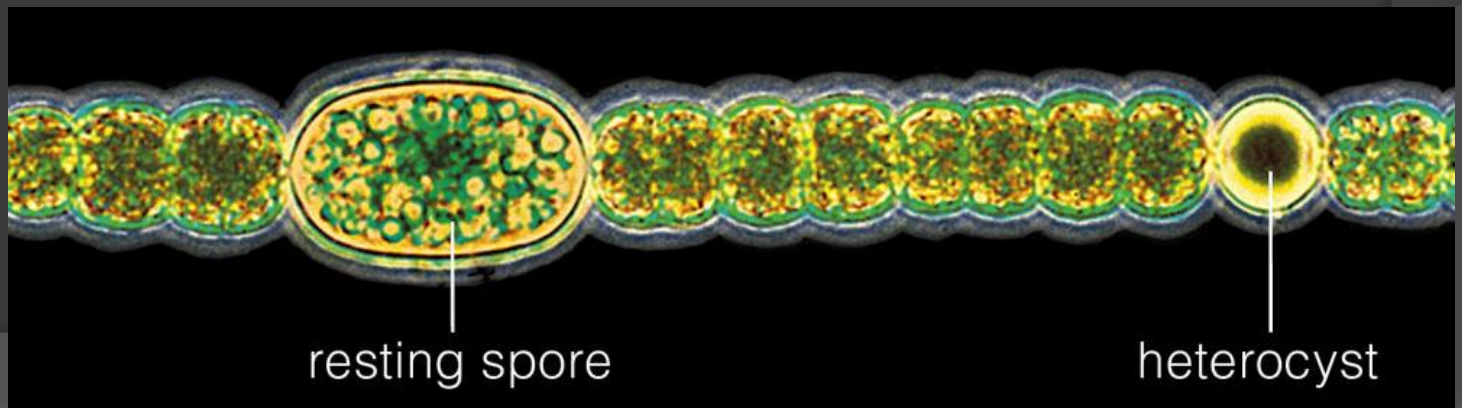
21.6 The Bacteria (Domain)

- Bacteria are the oldest, most diverse, and most abundant prokaryotic lineage
- Most are harmless or benefit us by releasing oxygen, fixing nitrogen, or cycling nutrients
- Some bacterial chemoheterotrophs cause disease in humans

Cyanobacteria

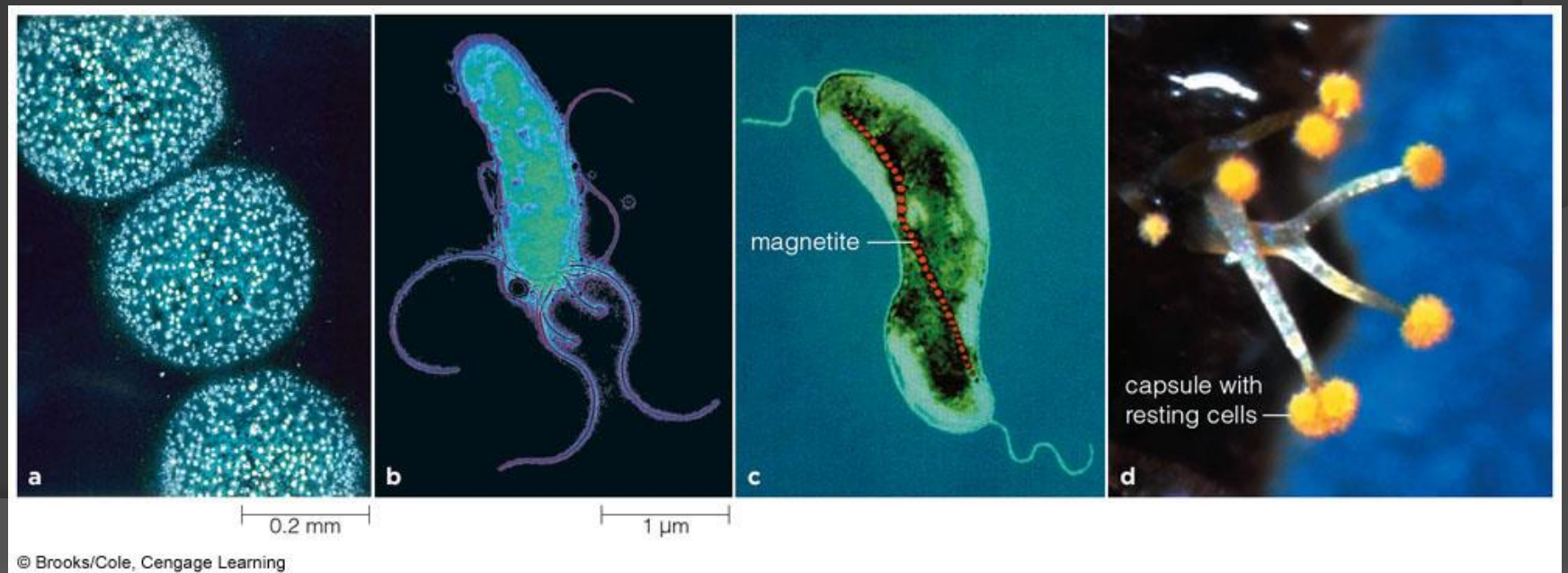
- Chloroplasts evolved from ancient **cyanobacteria**
  - Put oxygen in Earth's atmosphere

- **Nitrogen fixation**
  - Some cyanobacteria form heterocysts that fix atmospheric nitrogen (N_2) into ammonia (NH_3)



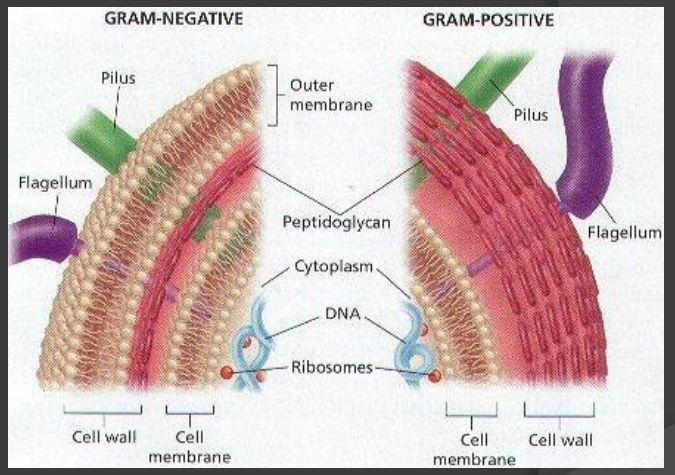
Metabolically Diverse Proteobacteria

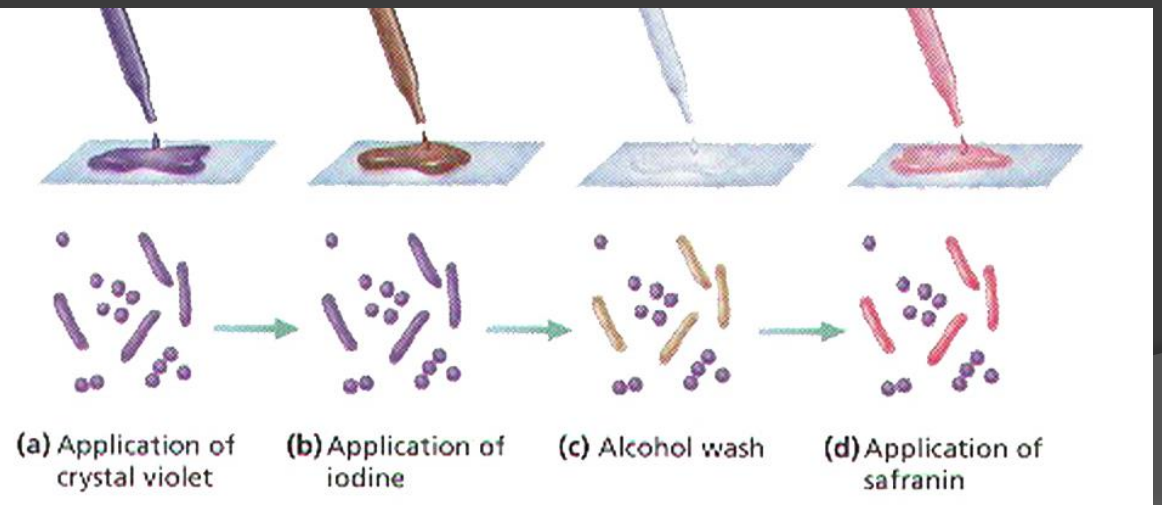
- *Thiomargarita namibiensis* strips electrons from sulfur
- *Helicobacter pylori* causes stomach ulcers
- Magnetotactic bacteria detect magnetic fields
- Myxobacteria form multicelled fruiting bodies

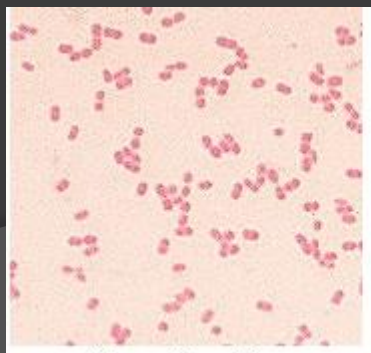


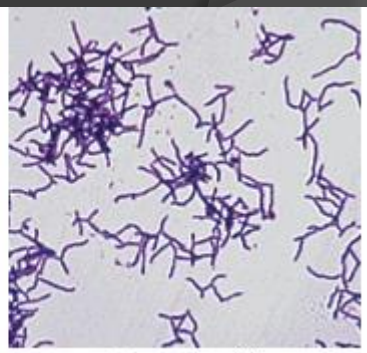
The Gram-Positive Heterotrophs

- Gram-positive bacteria have thick walls that stain purple by Gram-staining
  - Thin-walled bacteria (Gram-negative) stain pink
  - Gram-negative (as a whole are more pathogenic)

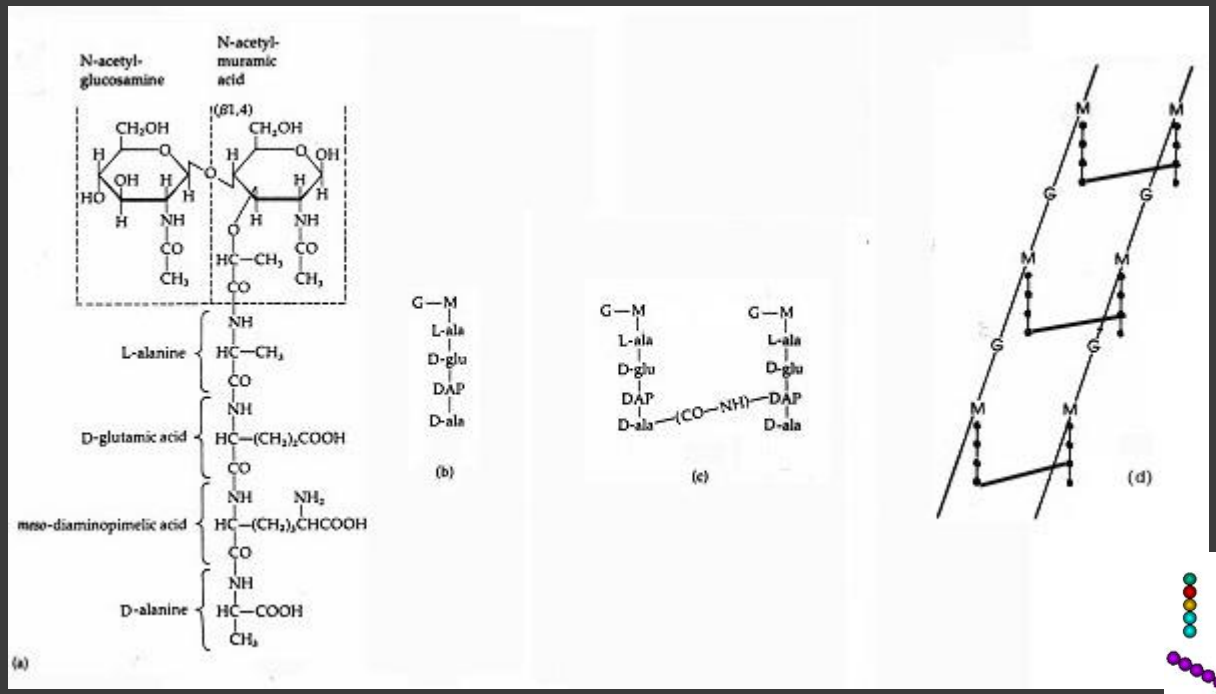


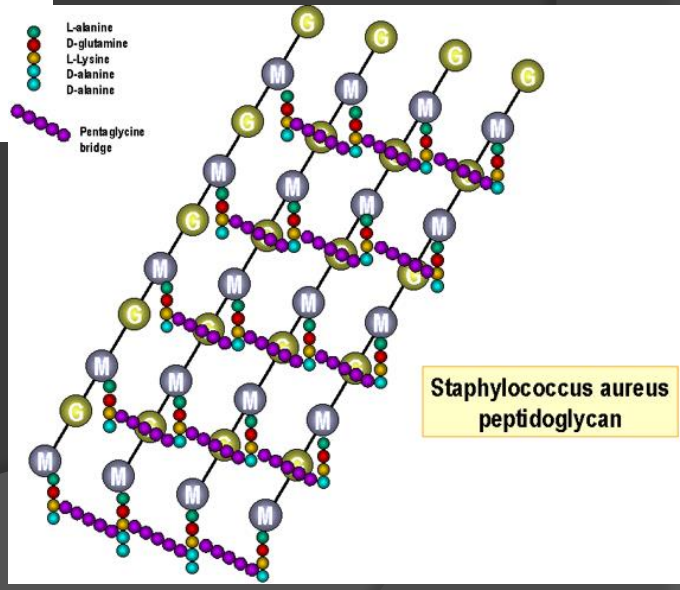



Gram Negative


Gram Positive

Structure of Peptidoglycan

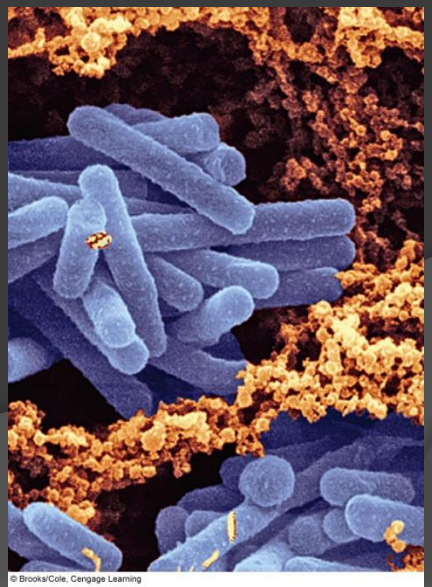




Gram positive bacteria

- *Lactobacillus* fermentation reactions produce yogurt and other foods

- *L. acidophilus lives on skin, gut, etc. – keeps pathogens in check*



Bacterial Diseases

- Pathogen = virus or bacteria that causes disease
- Bacteria cause disease by
  1) Destroying living cells directly of cause tissue damage when they provoke an immune response from the host
     - Tuberculosis (TB) is inhaled into the lungs and the immune response destroys tissue
  2) Release toxins that upset normal activities of the host
     - Botulism (gram +) – food poisoning
     - tetanus (gram +) – causes lockjaw, muscle spasms
     - Anthrax (gram +) – inhaled – interferes with breathing

Bacterial Diseases

Some Human Bacterial Diseases

Disease	Effect on Body	Transmission
Lyme disease	"Bull's-eye" rash at site of tick bite, fever, fatigue, headache	Ticks transmit the bacterium
Tetanus	Lockjaw, stiffness in neck and abdomen, difficulty swallowing, fever, elevated blood pressure, severe muscle spasms	Bacteria enter the body through a break in the skin.
Tuberculosis	Fatigue, weight loss, fever, night sweats, chills, appetite loss, bloody sputum from lungs	Bacteria particles are inhaled.
Bacterial meningitis	High fever, headache, stiff neck, nausea, fatigue	Bacteria are spread in respiratory droplets caused by coughing and sneezing; close or prolonged contact with someone infected with meningitis
Strep throat	Fever, sore throat, headache, fatigue, nausea	Direct contact with mucus from an infected person or direct contact with infected wounds or breaks in the skin

Controlling Bacteria

- Physical Removal
  – hand washing removes bacteria
- Disinfectants
  - chemicals that kill bacteria
- Food Storage –
  - refrigeration/freezing slows the growth
- Food Procession
  – boiling, frying, steaming kills bacteria
- Sterilization by Heat
  – kills bacteria

Controlling Bacteria (Cont.)

- Vaccines – a preparation of weakened or killed pathogen or inactivated toxin
  - The vaccine stimulates the body to produce immunity to a specific disease

- Antibiotics – block the growth and reproduction of bacteria
  - Disrupt proteins or cell processes specific to bacterial cells
  - Do not harm host's cells

Superbugs

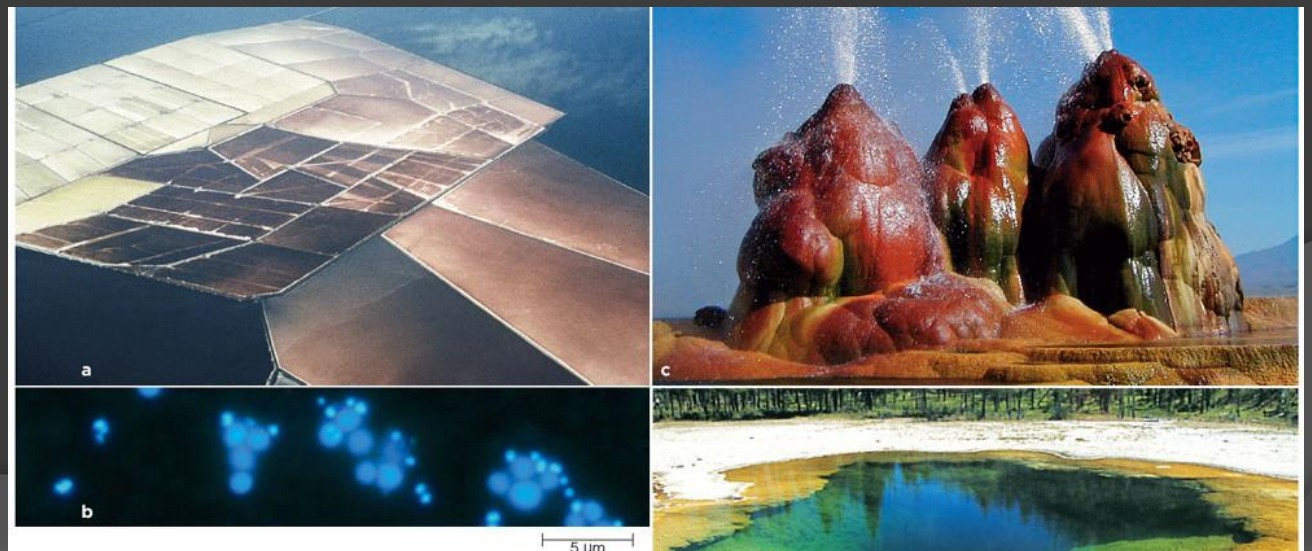
- Use of antibiotics has lead to bacteria that are resistant to antibiotics
  - Penicillin killed many infections in the 1940s when it was introduced. Now is has lost effectiveness
  - Bacteria that are resistant to penicillin reproduce and pass resistance on through conjugation
  - MRSA – skin infection spread by close contact

Incidence of MRSA	
Year	Hospital Cases Reported
1993	1900
1995	38,100
1997	69,800
1999	108,600
2001	175,000
2003	248,300
2005	368,600


Bacillus
Salsa Experiment
Bacillus
Salsa Experiment
A
B

21.7 The Archaeans

- Archaeans, the more recently discovered prokaryotic lineage, are the third domain – the closest prokaryotic relatives of eukaryotes
- Archaeans live everywhere – many live in very hot or very salty habitats
- Hardly any archaeans cause human disease



Archaean Physiology

- **Methanogens** (methane producers)
  - Strict anaerobes

- **Extreme halophiles** (salt lovers)
  - Aerobic or photosynthetic

- **Extreme thermophiles** (heat lovers)
  - Chemoautotrophs or heterotrophs

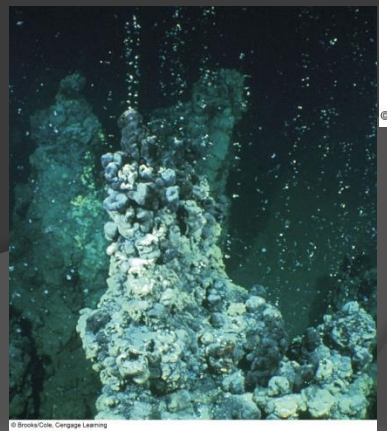


TABLE 1. COMPARISON OF THE THREE DOMAINS

Characteristics	Archaea	Bacteria	Eukarya
Distinguishing small subunit rRNA nucleotide base sequence positions	180 to 197; 405 to 498	500 to 545	585 to 655
Membrane lipids	Ether-linked	Ester-linked	Ester-linked
Predominantly multicellular	No	No	Yes
Cell wall	Yes	Yes	No
Peptidoglycan	Yes	No	No
Membrane-bound organelles	No	No	Yes
Survival above 80 °C	Yes	Yes	No
Ribosomes	70S	70S	80S
Circular DNA	Yes	Yes	No
Histones	Yes	No	Yes
Transcription factors required	No	Yes	Yes
RNA polymerase	Several	One	Three
Initiator tRNA	Methionine	Formylmethionine	Methionine
Introns in tRNA	Yes	No	Yes

21.1 Viral Characteristics and Diversity

- A virus consists of nucleic acid and protein
- A virus is smaller than any cell and has no metabolic machinery of its own
- Noncellular infectious particles that multiply only inside living cells
- Some viruses cause disease (**pathogens**); others control disease-causing organisms

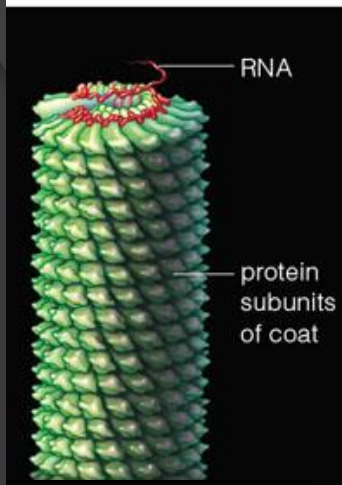
Characteristics of a Virus

Table 21.1 Characteristics of a Virus

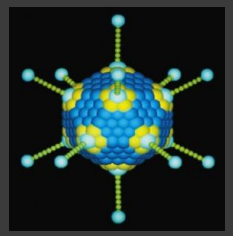
1. Noncellular; no cytoplasm, ribosomes, or other typical cell components
2. Genetic material may be DNA or RNA
3. Can only replicate inside a living host cell
4. Small (about 25 to 300 nanometers); nearly all are visible only with an electron microscope

Examples of Viruses

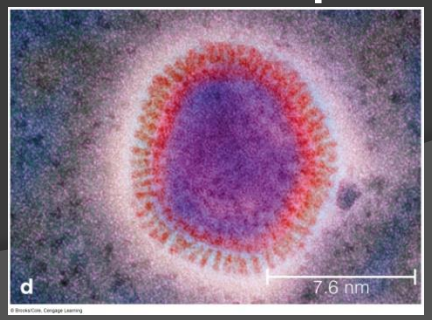
- Viruses that infect plants (tobacco mosaic virus)

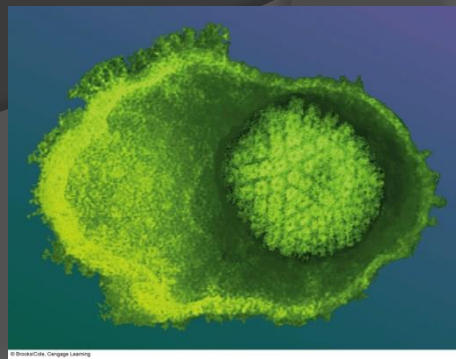


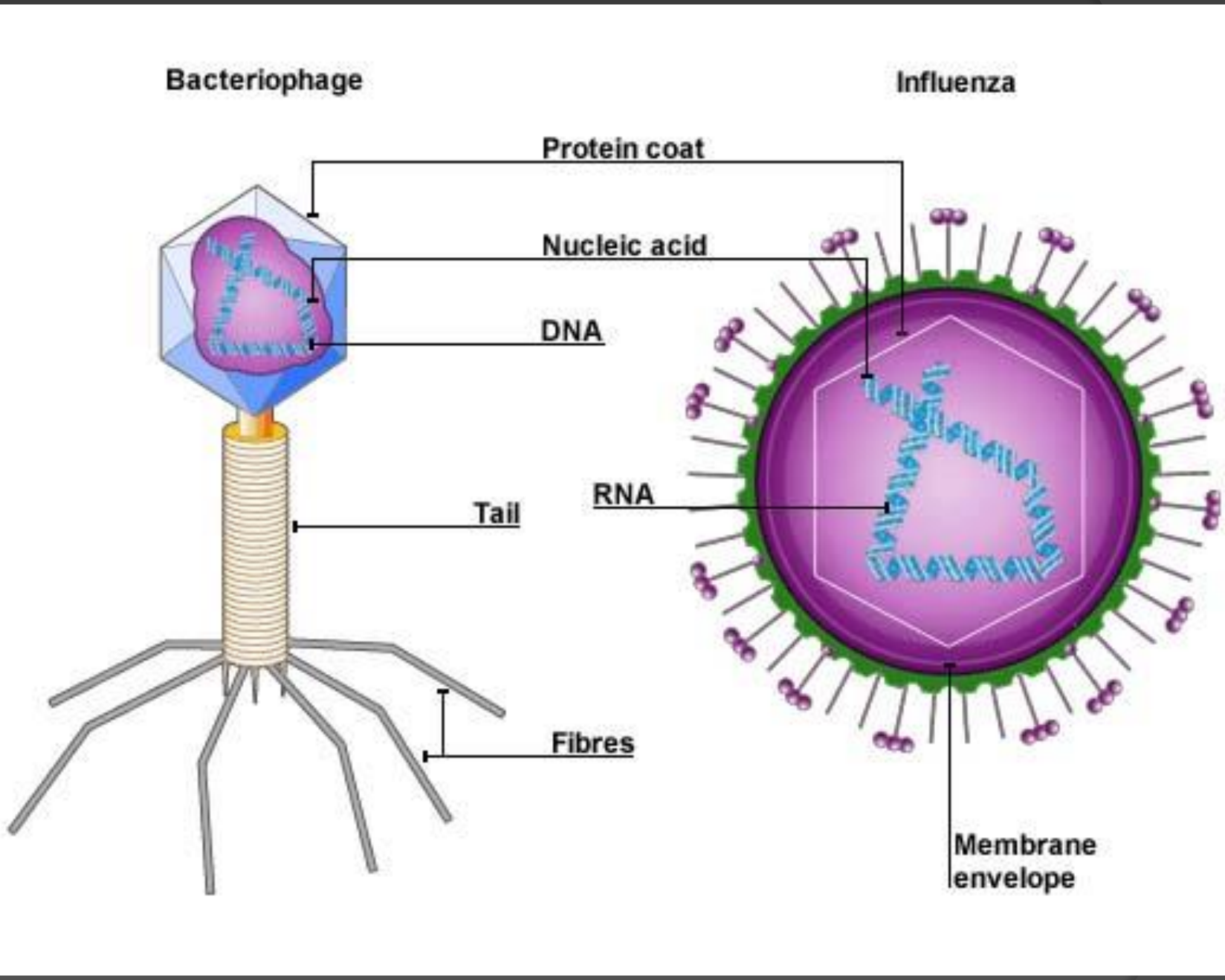
- Viruses that infect bacteria or archaeans (**bacteriophages**)



- Naked viruses (adenoviruses)
  - Eye infections, common cold, hepatitis, warts
- Enveloped viruses (influenza, herpesviruses, HIV, West Nile, rabies)






Bacteriophage
Influenza
Protein coat
Nucleic acid
DNA
RNA
Tail
Fibres
Membrane envelope

Viral Origins and Evolution

- Three hypotheses:
  - Viruses may have descended from cells that were parasites of other cells
  - Viruses may be genetic elements that escaped from cells
  - Viruses may represent a separate evolutionary branch

Steps in Viral Replication

Table 21.2 Steps in Most Viral Multiplication Cycles

1. Attachment Proteins on viral particle chemically recognize and lock onto specific receptors at the host cell surface.

2. Penetration Either the viral particle or its genetic material crosses the plasma membrane of a host cell and enters the cytoplasm.

3. Replication and synthesis Viral DNA or RNA directs host to make viral nucleic acids and viral proteins.

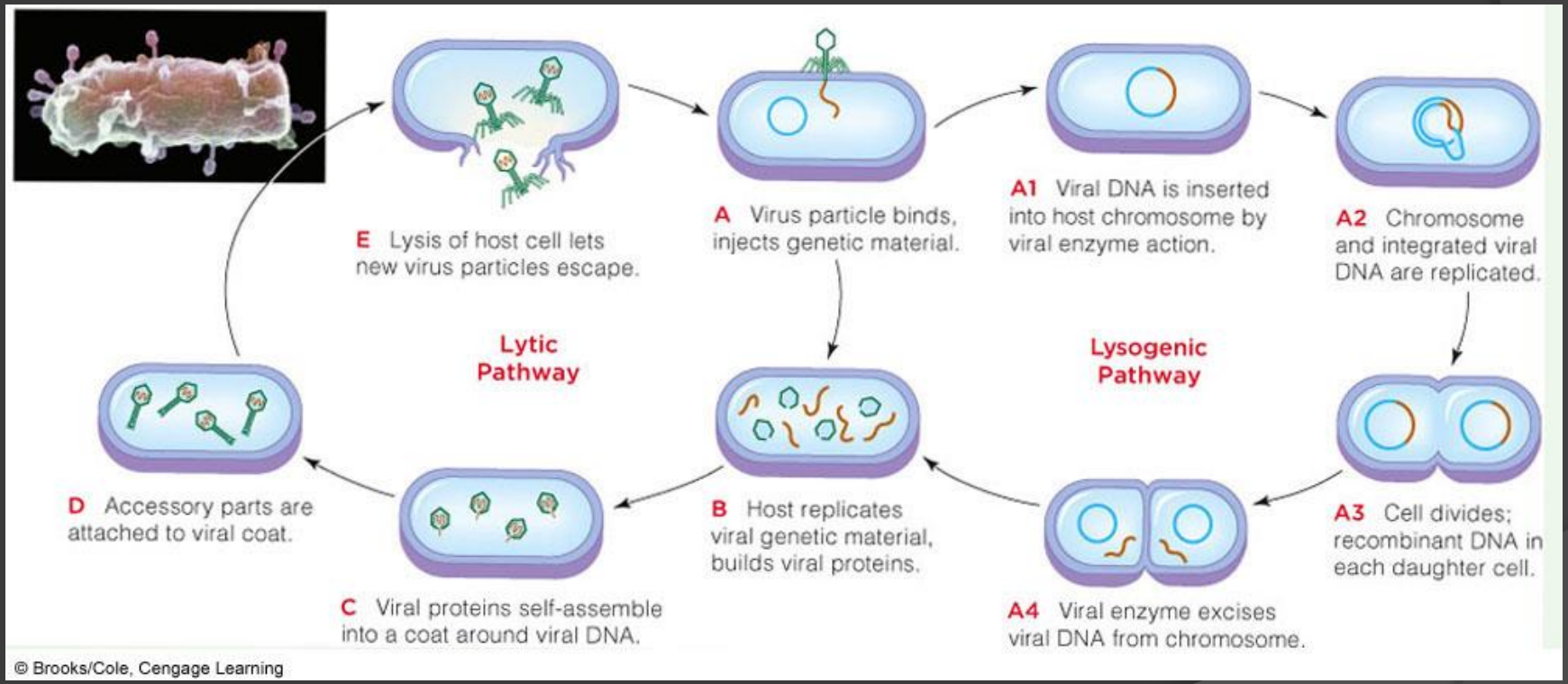
4. Assembly Viral components assemble as new viral particles.

5. Release The new viral particles are released from the cell.

Bacteriophage Replication

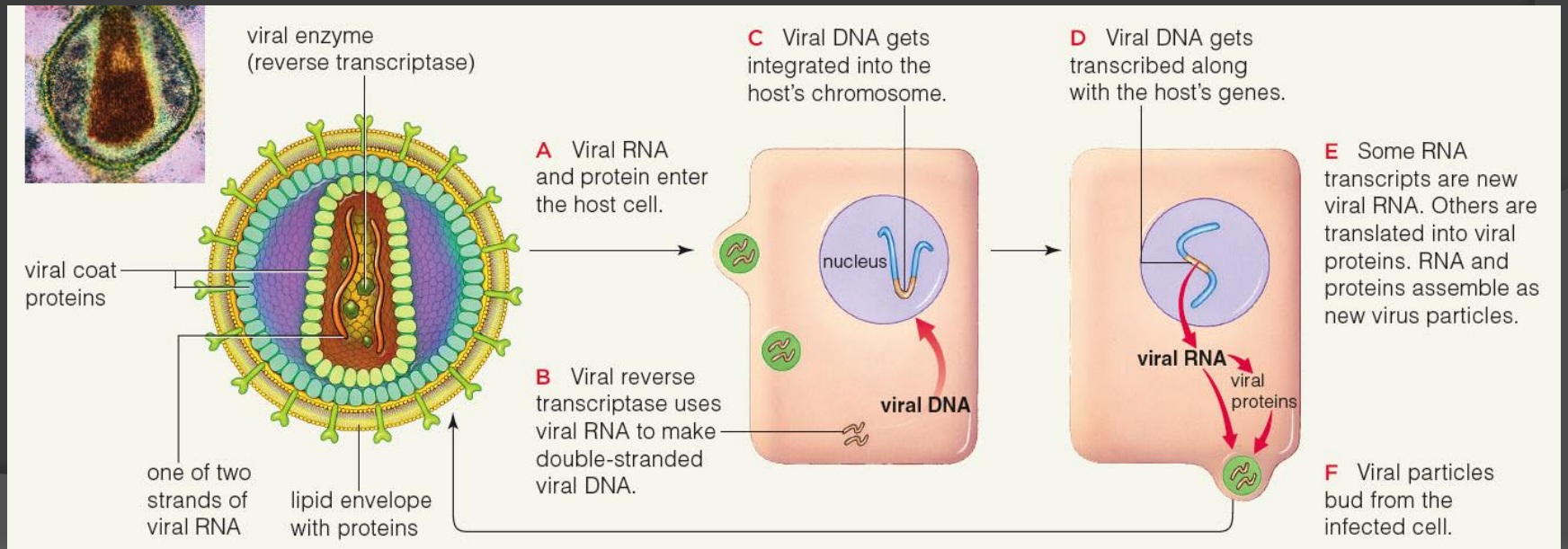
- **Lytic pathway**
  - Under direction of viral genes, the host makes an enzyme that lyses and kills the cell
- **Lysogenic pathway**
  - Virus enters a latent state
  - Host replicates viral genes and passes them on to descendents before entering lytic pathway

Bacteriophage Replication



Replication of a Retrovirus - HIV

- Virus binds to receptors on white blood cells; viral envelope fuses with host membrane; viral RNA enters host cytoplasm
- Enzyme (**reverse transcriptase**) converts viral RNA to DNA, which integrates with host DNA
- Host cell produces viral RNA and proteins which assemble into new viral particles
- New viruses are enveloped in host plasma membrane and exit by exocytosis



Viral Diseases

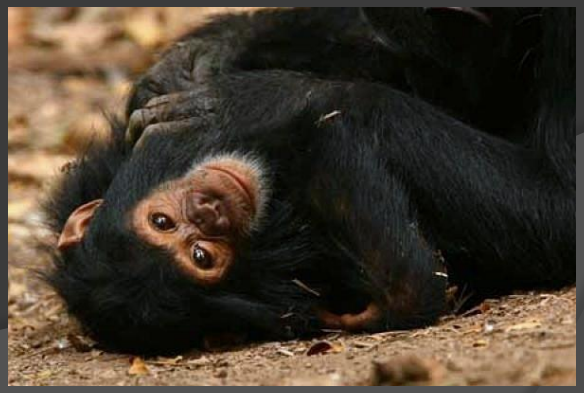
- Viruses also cause disease by
  1) destroying cells directly
  2) interrupting cellular processes

Some Human Viral Diseases

Disease	Effect on Body	Transmission
Common cold	Sneezing, sore throat, fever, headache, muscle aches	Contact with contaminated objects; droplet inhalation
Influenza	Body aches, fever, sore throat, headache, dry cough, fatigue, nasal congestion	Flu viruses spread in respiratory droplets caused by coughing and sneezing.
AIDS	Helper T cells, which are needed for normal immune-system function, are destroyed.	Contact with contaminated blood or bodily fluids; mothers can pass it to babies during delivery or during breastfeeding.
Chicken pox	Skin rash of blisterlike lesions	Virus particles are spread in respiratory droplets caused by coughing and sneezing; highly contagious
Hepatitis B	Jaundice, fatigue, abdominal pain, nausea, vomiting, joint pain	Contact with contaminated blood or bodily fluids
West Nile	Fever, headache, body ache	Bite from an infected mosquito
Human papillomavirus (HPV)	Genital or anal warts, also cancer of the cervix, penis, and anus	Sexual contact

New Viruses

- Genetic makeup of viruses changes quickly and allows a virus to jump form one species to another.
  - AIDS may have jumped from nonhuman primates
  - “Bird flu” is a concern because it may jump to humans and is similar to some of the most deadly human versions of the flu



Prevention and Treatment for Viral Diseases

- Preventing viral diseases
  1) Vaccines
  2) Personal hygiene

  -wash hands

  -avoid sick people

  -cough into a tissue or sleeve

- There are a handful of antiviral drugs

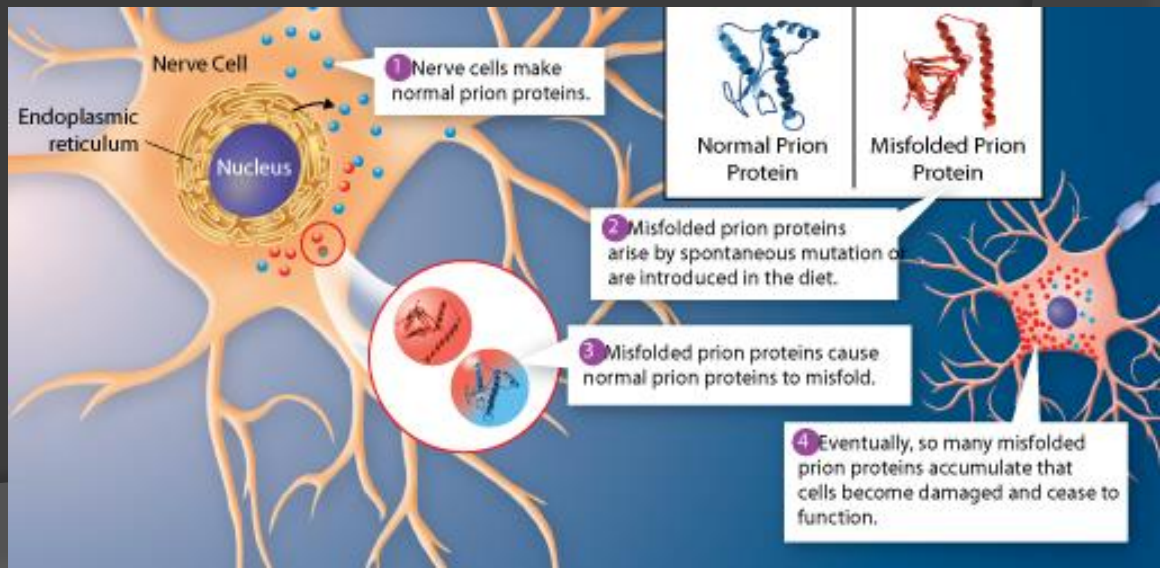
  - Speed recovery from flu/may reduce spread of HIV

21.3 Viroids and Prions

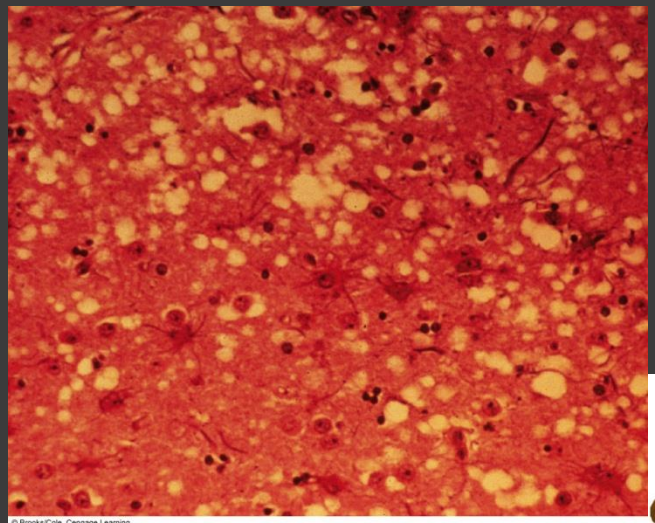
- Viroids and prions are infectious particles that are even simpler than viruses
- **Viroid**
  - Infectious RNA, not surrounded by a protective protein coat (mostly plants – only 1 in humans that interacts with a virus in liver cells = hepatitis D)
- **Prion**
  - Proteins in the nervous system that can misfold, and cause other prions to misfold

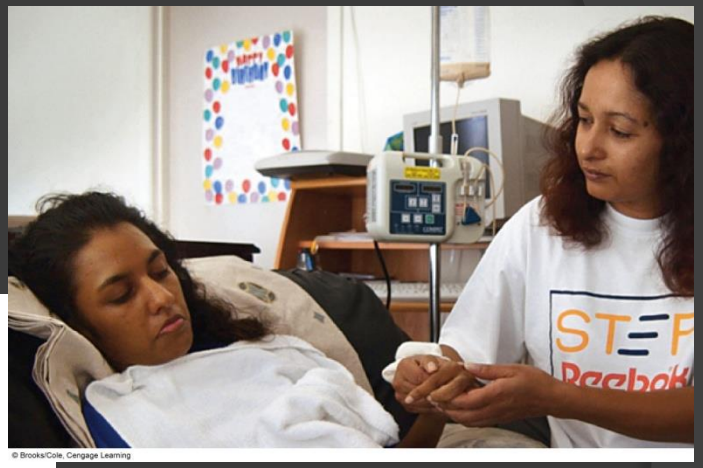
Prion Diseases

- Scrapie: A prion disease that affects sheep
- Bovine spongiform encephalopathy (BSE or mad cow disease): Affects cattle that have eaten feed made with infected sheep
- Variant Creutzfeldt-Jacob disease (vCJD): Affects humans who have eaten infected beef
- Kuru



Prion Diseases





Emerging Diseases

- Emerging diseases = an unknown disease that appears in a population for the first time or a well-known disease that has become harder to control
  - Pathogens that cause emerging diseases are threatening because humans have little or no resistance for them and control methods have not been developed
  - Human populations once isolated are now connected – quick spread of disease – Rx for survival – How safe are we?
    AIDS – 0-23:00 then Cholera-SARS –Birdflu