PROKARYOTES

© 2018 Pearson Education Ltd.

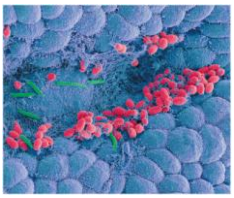
Introduction

- Microorganisms residing in and on your body outnumber your own cells.
- Bacteria were once classified as plants which gave rise to use of the term ***flora*** for microbes. This term has been replaced by ***microbiota***.
- Microbes normally present in and on the human body are called normal microbiota.
  - Normal microbiota prevent growth of pathogens and produce growth factors such as folic acid and vitamin K.
- Scientists hypothesize that disrupting our microbial communities may
  - increase our susceptibility to infectious diseases,
  - predispose us to certain cancers, and
  - contribute to conditions such as asthma and other allergies, irritable bowel syndrome, Crohn's disease, and autism.

© 2018 Pearson Education Ltd.

Colorized SEM 525×

Bacteria on the point of a pin



Helicobacter pylori (green) and yeast cells (red) situated on cells lining the stomach.

© 2018 Pearson Education Ltd.

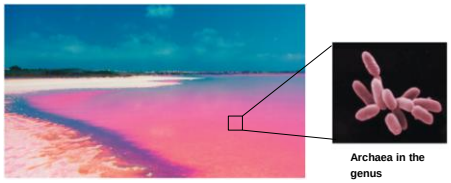
Microbes on 8-Year-Old boy's handprint after playing outside.

This colorful petri dish is full of bacteria, yeast and fungi

© 2018 Pearson Education Ltd.

Masters of Adaptation

- The waters of Laguna Salada de Torrevieja in Spain (the "Salty Lagoon") are many times saltier than seawater
- At certain times of the year, the water appears pink
- The color comes from trillions of living prokaryotes



Archaea in the genus *Halobacterium*

© 2018 Pearson Education Ltd.

- Prokaryotic cells are smaller than eukaryotic cells.
- The collective biomass of prokaryotes is at least 10 times that of all eukaryotes.
- Prokaryotes have an immense impact on the environment and on our health.
- Prokaryotes thrive almost everywhere, including places too acidic, salty, cold, or hot for most other organisms
- Due to their ability to adapt to diverse habitats, prokaryotes are the most abundant organisms on Earth
- Prokaryotes are divided into two domains: bacteria and archaea

© 2018 Pearson Education Ltd.

Archaea thrive in extreme environments—and in other habitats

- Domain Archaea includes
  - **extreme halophiles** ("salt lovers"),
  - **extreme thermophiles** ("heat lovers"), and
  - **methanogens**, which thrive in anaerobic conditions; live in swamps and marshes and produce methane as a waste product.

Checkpoint question Some archaea are referred to as "extremophiles." Why?

© 2018 Pearson Education Ltd.

Figure 27.17 Extreme thermophiles. Orange and yellow colonies of thermophilic prokaryotes grow in the hot water of Yellowstone National Park's Grand Prismatic Spring.

Pipes for collecting gas from a landfill

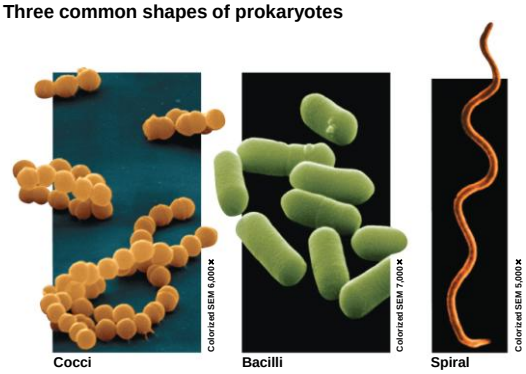
© 2018 Pearson Education Ltd.

Structural and functional adaptations contribute to prokaryotic success

- Prokaryotes were the first organisms to inhabit the Earth
- Most are unicellular, although some species form colonies
- Most prokaryotic cells are 0.5–5 μm, much smaller than the 10–100 μm of many eukaryotic cells
- Prokaryotic cells have a variety of shapes
- The three most common shapes are spheres (**cocci**), rods (**bacilli**), and **spirals**

© 2018 Pearson Education Ltd.

Three common shapes of prokaryotes



Cocci Bacilli Spiral

Cell-Surface Structures

- The cell wall maintains cell shape, protects the cell, and prevents it from bursting in a hypotonic environment
- Most bacterial cell walls contain **peptidoglycan**, a network of sugar polymers cross-linked by polypeptides
- Many antibiotics target peptidoglycan and damage bacterial cell walls
- A sticky outer layer of polysaccharide or protein called a **capsule** is present in some prokaryotes
- The capsule allows adherence to the substrate, or other individuals, and can shield pathogenic bacteria from the host immune system

© 2018 Pearson Education Ltd.

Populations of prokaryotes can adapt rapidly to changes in the environment

- Rapid prokaryote population growth generates a great deal of genetic variation, increasing the likelihood that the population will persist in a changing environment.
- Some prokaryotes form **endospores** that remain dormant through harsh conditions.

Checkpoint question Why does rapid reproduction produce high genetic variation in populations of prokaryotes?

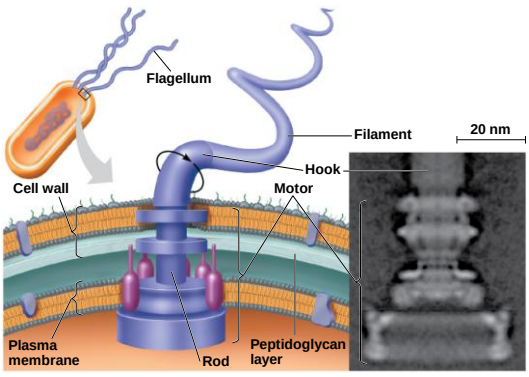
© 2018 Pearson Education Ltd.

© 2018 Pearson Education Ltd.

Motility

- About half of all prokaryotes exhibit **taxis**, the ability to move toward or away from a stimulus
  - For example, chemotaxis is the movement toward or away from a chemical stimulus
- Flagella are the most common structures used by prokaryotes for movement
- Flagella may be scattered about the surface or concentrated at one or both ends of the cell
- The flagella of prokaryotes and eukaryotes differ in structure, mechanism of propulsion, and molecular composition

© 2018 Pearson Education Ltd.



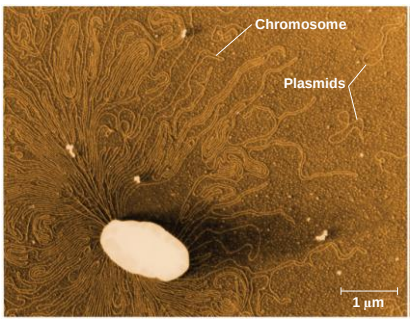
© 2018 Pearson Education Ltd.

Genome

- The prokaryotic genome has less DNA than the eukaryotic genome
- Most of the genome consists of a circular chromosome
- The chromosome is not contained in a nucleus; it is located in the **nucleoid** region with no surrounding membrane
- Typical prokaryotes also have smaller rings of independently replicating DNA called **plasmids**

© 2018 Pearson Education Ltd.

A prokaryotic chromosome and plasmids of a ruptured bacterium



© 2018 Pearson Education Ltd.

- There are some differences between prokaryotes and eukaryotes in DNA replication, transcription, and translation
- These differences allow people to use certain antibiotics to inhibit bacterial growth without harming themselves

© 2018 Pearson Education Ltd.

Reproduction

- Key features of prokaryote biology:
  - They are small
  - They reproduce by binary fission
  - They have short generation times: divide every 1–3 hours under optimal conditions
- Prokaryotes have considerable genetic variation
- Three factors contribute to this genetic diversity:
  - Rapid reproduction
  - Mutation
  - Genetic recombination

© 2018 Pearson Education Ltd.

Rapid Reproduction and Mutation

- Mutations accumulate rapidly because generation times are short and populations are large
- Prokaryotes have simpler cells than eukaryotes, but their rapid adaptation to environmental change indicates that they are highly evolved

© 2018 Pearson Education Ltd.

Prokaryotes have unparalleled nutritional diversity

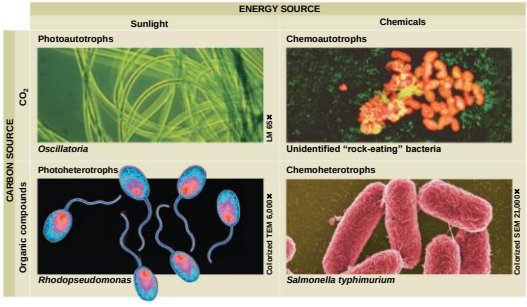
- Prokaryotes exhibit much more nutritional diversity than eukaryotes. This allows them to inhabit almost every place on Earth.
- Two sources of energy can be used by prokaryotes.
  - Like plants, prokaryotic phototrophs capture energy from sunlight.
  - Prokaryotes called chemotrophs harness the energy stored in chemicals.

© 2018 Pearson Education Ltd.

- Prokaryotes can be categorized by how they obtain energy and carbon:
  - Phototrophs obtain energy from light
  - Chemotrophs obtain energy from chemicals
  - Autotrophs require CO_2 or related compounds as a carbon source
  - Heterotrophs require an organic nutrient to make organic compounds

© 2018 Pearson Education Ltd.

Sources of energy and carbon in prokaryotic modes of nutrition



© 2018 Pearson Education Ltd.

Nutritional mode	Energy source	Carbon source
Photoautotroph	Sunlight	CO_2
Chemoautotroph	Inorganic chemicals	
Photoheterotroph	Sunlight	Organic compounds
Chemoheterotroph	Organic compounds	

Which term would describe your mode of nutrition?

© 2018 Pearson Education Ltd.

Biofilms are complex associations of microbes

- Prokaryotes attach to surfaces and form highly organized **biofilm** communities that are difficult to eradicate, causing both medical and environmental problems.
- Sulfate-consuming bacteria and methane-consuming bacteria on the ocean floor use each other's waste products

Checkpoint question

Why are biofilms difficult to eradicate?

© 2018 Pearson Education Ltd.

Prokaryotes in Research and Technology

- Experiments using prokaryotes have led to important advances in DNA technology
  - E.g. *E. coli* is used in gene cloning
  - E.g. the prokaryotic CRISPR-Cas system can alter genes in other organisms
- Bacteria can be used to make natural plastics
- Bacteria are also being engineered to produce ethanol from agricultural and municipal waste biomass, switchgrass, and corn

© 2018 Pearson Education Ltd.

Prokaryotes play crucial roles in the biosphere

- A world of eukaryotes cannot exist without prokaryotes
- Prokaryotes are so important that if they were to disappear, the prospects for any other life surviving on Earth would be dim
- Prokaryotes play a major role in the recycling of chemical elements between the living and nonliving components of the environment
- Some chemoheterotrophic prokaryotes function as **decomposers**, breaking down dead organisms and waste products

© 2018 Pearson Education Ltd.

- Prokaryotes can convert some molecules to forms that can be taken up by other organisms
  - For example, under some conditions, prokaryotes can increase the availability of nutrients required for plant growth
- Prokaryotes can also "immobilize" or decrease the availability of nutrients by using them in their own cells

© 2018 Pearson Education Ltd.

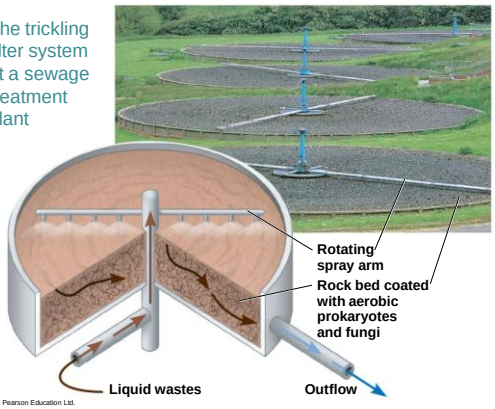
Prokaryotes help clean up the environment

- **Bioremediation** is the use of organisms to remove pollutants from soil, air, or water.
- Prokaryotes are often used for bioremediation, including in sewage treatment facilities.

Checkpoint question How might an influx of toxic chemicals affect the ability of a wastewater treatment plant to treat sewage?

© 2018 Pearson Education Ltd.

The trickling filter system at a sewage treatment plant



© 2018 Pearson Education Ltd.

Spraying chemical dispersants on oil spill in the Gulf of Mexico, 2010- Deepwater Horizon

© 2018 Pearson Education Ltd.

Ecological Interactions

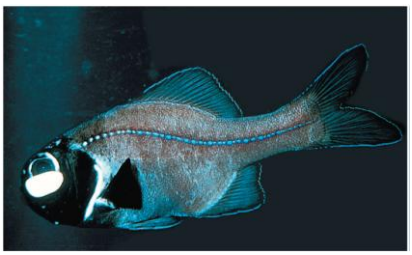
- **Symbiosis** is an ecological relationship in which two species live in close contact: a larger **host** and smaller **symbiont**
- Prokaryotes often form symbiotic relationships with larger organisms

© 2018 Pearson Education Ltd.

- In **mutualism**, both symbiotic organisms benefit
- In **commensalism**, one organism benefits while neither harming nor helping the other in any significant way
- In **parasitism**, an organism called a **parasite** harms but does not kill its host
- Parasites that cause disease are called **pathogens**

© 2018 Pearson Education Ltd.

Mutualism: bacterial "headlights"



The glowing oval below the eye of the flashlight fish (*Photoblepharon palpebratus)* is an organ harboring bioluminescent bacteria

© 2018 Pearson Education Ltd.

- The existence of some ecosystems depends on prokaryotes
  - For example, the ecological communities of hydrothermal vents depend on chemoautotrophic bacteria for energy

© 2018 Pearson Education Ltd.

Prokaryotes have both beneficial and harmful impacts on humans

- Some prokaryotes are human pathogens, but many others have positive interactions with humans

Mutualistic Bacteria

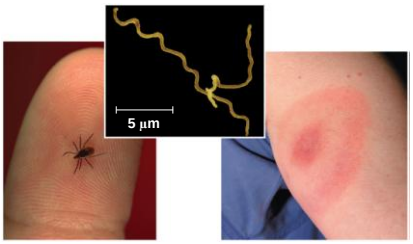
- Human intestines are home to about 500–1,000 species of bacteria
- Many of these are mutualists and break down food that is undigested by our intestines

Pathogenic Bacteria

- Bacteria cause about half of all human diseases
- Some bacterial diseases are transmitted by other species
- For example, Lyme disease is caused by a bacterium and carried by ticks

© 2018 Pearson Education Ltd.

Lyme disease



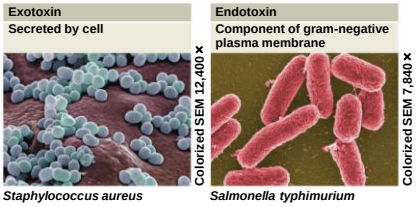
Ticks in the genus *Ixodes* spread the disease by transmitting the spirochete *Borrelia burgdorferi* (colorized SEM). A rash may develop at the site of the tick's bite; the rash may be large and ring-shaped (as shown) or much less distinctive.

© 2018 Pearson Education Ltd.

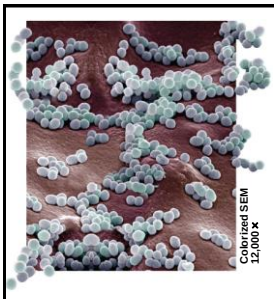
Some bacteria cause disease

- Pathogenic bacteria often cause disease by producing
  - **exotoxins**, proteins that bacterial cells secrete into their environment (even if the prokaryotes that produce them are not present), or
  - **endotoxins**, lipid components of the outer membrane of gram-negative bacteria that are released when the cell dies or is digested.
- Certain bacteria, such as the species that causes anthrax, and bacterial toxins, such as botulinum, can be used as biological weapons.

© 2018 Pearson Education Ltd.



© 2018 Pearson Education Ltd.



Staphylococcus aureus, an exotoxin producer

Injecting Botox, which contains a minute amount of botulinum, to smooth wrinkles

© 2018 Pearson Education Ltd.

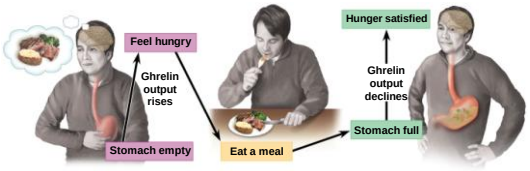
Stomach microbiota affect health and disease

- Barry Marshall used Koch's postulates to show that peptic ulcers are usually caused by a bacterium, *Helicobacter pylori*.
- Researchers are now beginning to learn that *H. pylori* may also have beneficial roles in the stomach microbiota.

Barry Marshall (left) and collaborator Robin Warren after winning the 2005 Nobel Prize in Medicine for their discovery of *H. pylori* (inset) and its role in peptic ulcers

© 2018 Pearson Education Ltd.

Effect of ghrelin on hunger



H. pylori is thought to affect the stomach's production of a hormone called **ghrelin** that sends hunger signals to the brain

© 2018 Pearson Education Ltd.