Chapter 16

The Origin and Evolution of Microbial Life: Prokaryotes and Protists

PowerPoint Lectures for

Biology: Concepts & Connections, Sixth Edition

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Lecture by Joan Sharp

Introduction: *How Ancient Bacteria Changed the World*

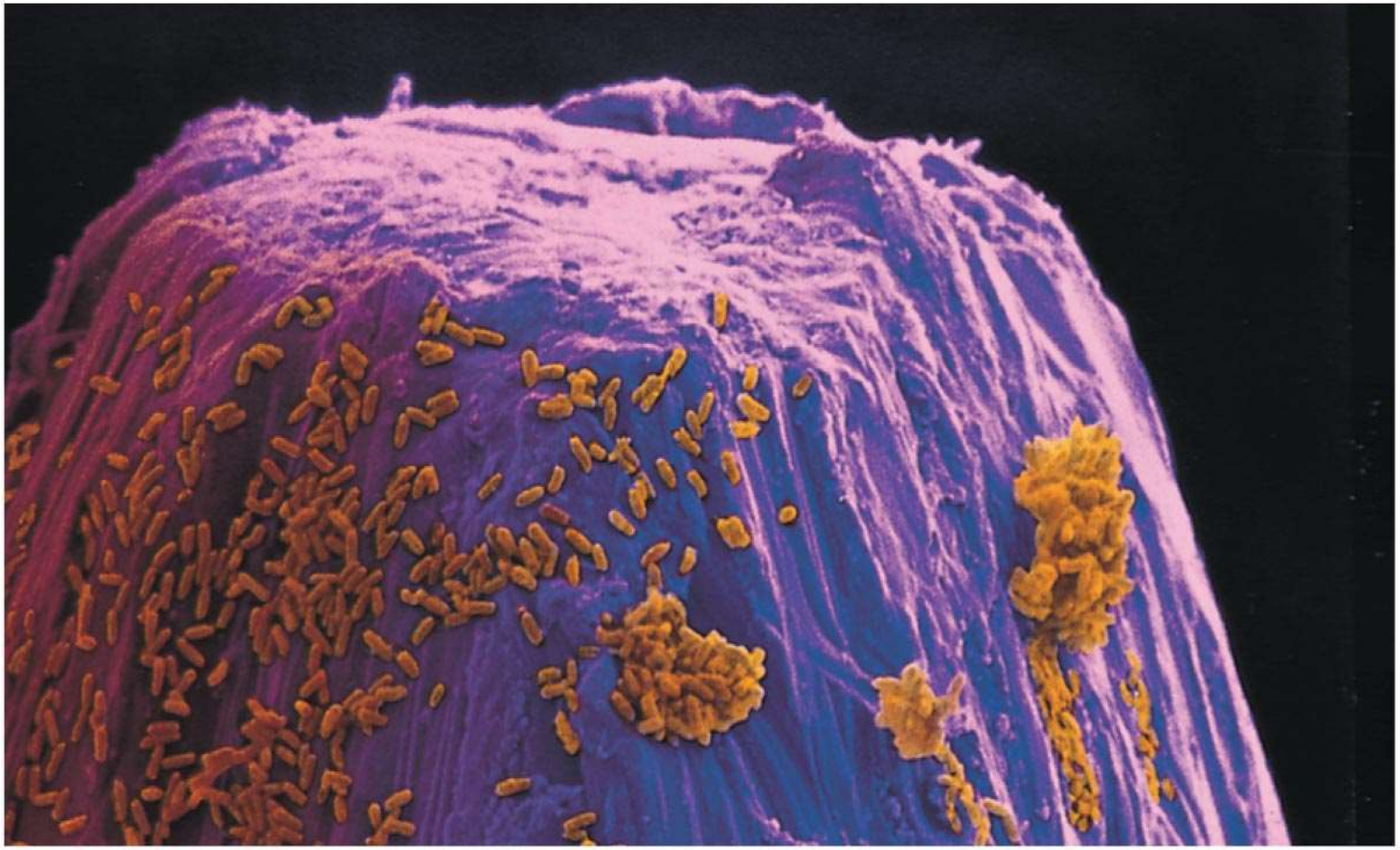
- Virtually all metabolic pathways on Earth evolved in prokaryotic cells, before the evolution of eukaryotes
- The products generated by prokaryotic metabolism changed the Earth's atmosphere and rocks
- Fossilized stromatolites from 3 billion years ago contain the fossils of photosynthetic cyanobacteria
  - These bacteria produced O_2 and made Earth's atmosphere aerobic

16.1 Prokaryotes are diverse and widespread

- Prokaryotes lived alone on Earth for over 1 billion years
  - They remain the most numerous and widespread organisms on Earth
  - The total biomass of prokaryotes is ten times that of eukaryotes

16.1 Prokaryotes are diverse and widespread

- Most prokaryotes are 1–5 μm in diameter (vs. 10–100 μm for eukaryotic cells)
- More prokaryotes live in your mouth than the total number of humans that have ever lived
- There are ten times as many prokaryotes living in and on your body as the number of cells in your body

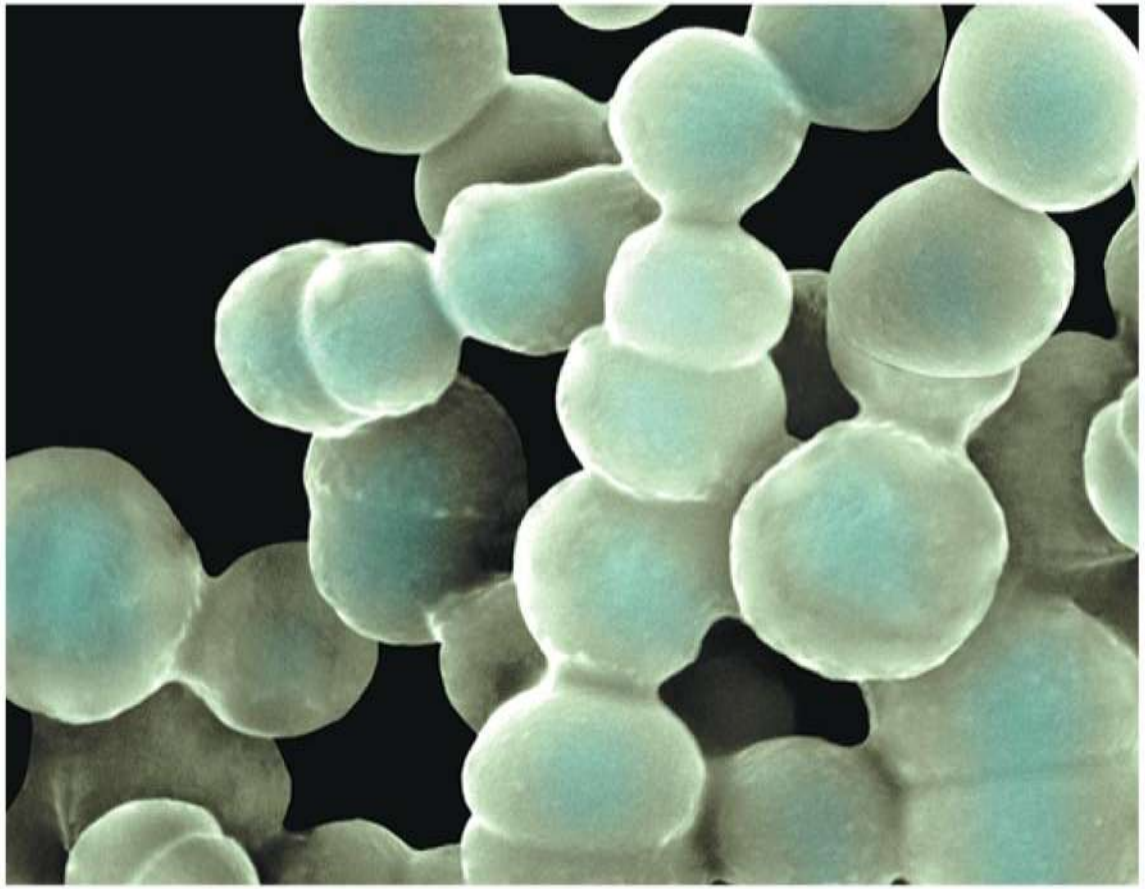


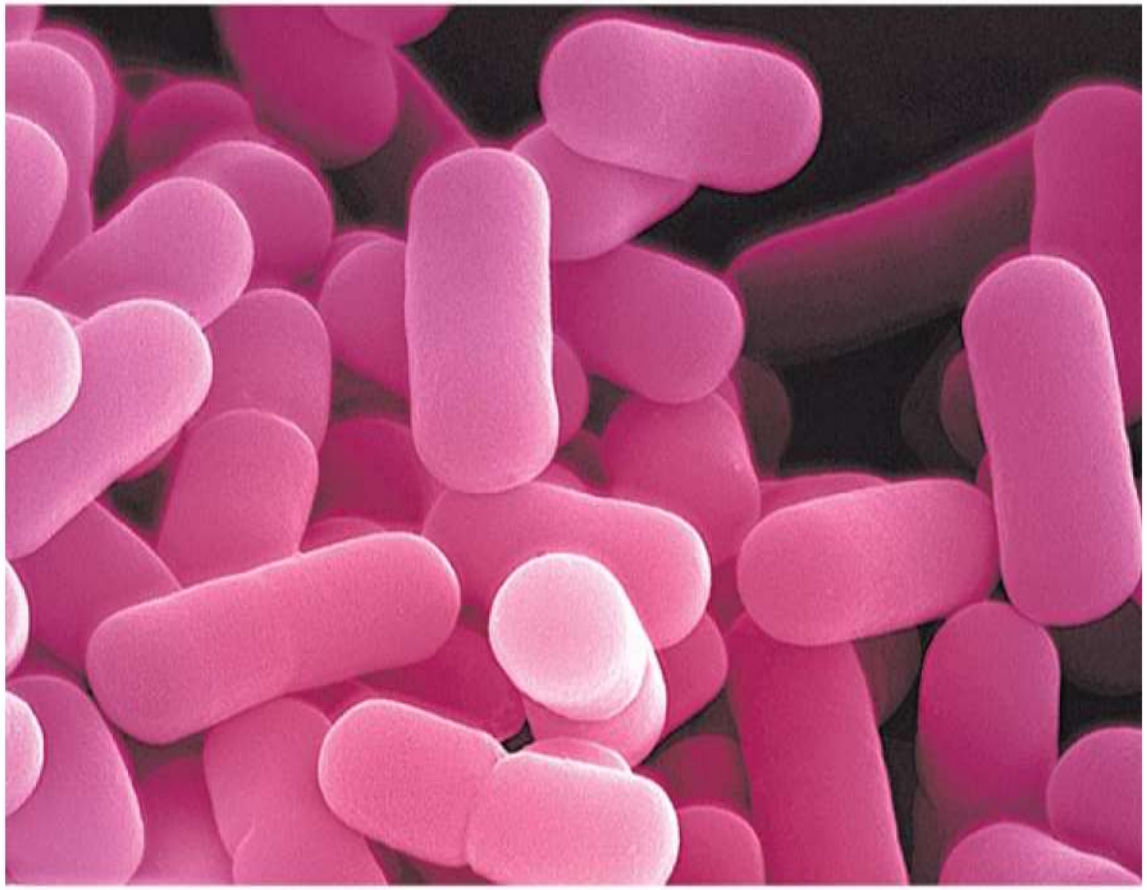
16.1 Prokaryotes are diverse and widespread

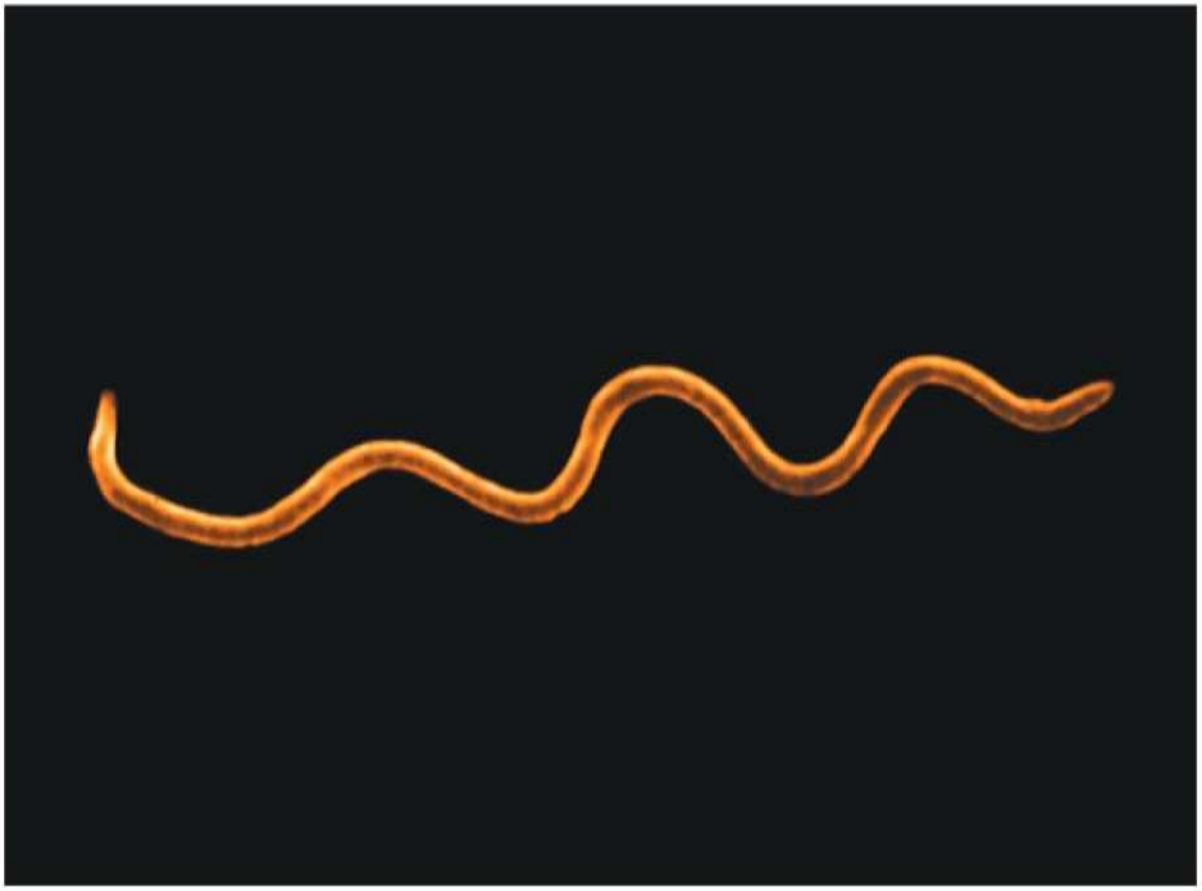
- Prokaryotes live in cold, hot, salty, acidic, and alkaline habitats
- Although some bacteria are **pathogenic** and cause disease, most bacteria on our bodies are benign or beneficial
  - Several hundred species of bacteria live in and on our bodies, decomposing dead skin cells, supplying essential vitamins, and guarding against pathogenic organisms
- Prokaryotes in soil decompose dead organisms, sustaining chemical cycles

16.2 Bacteria and archaea are the two main branches of prokaryotic evolution

- The two prokaryotic domains, **Bacteria** and **Archaea**, diverged soon after life on Earth arose
- Present day Archaea and Eukarya evolved from a common ancestor, complicated by gene transfer between prokaryotic lineages
- Some genes of Archaea are similar to bacterial genes, some are similar to eukaryotic genes, and some are unique to Archaea



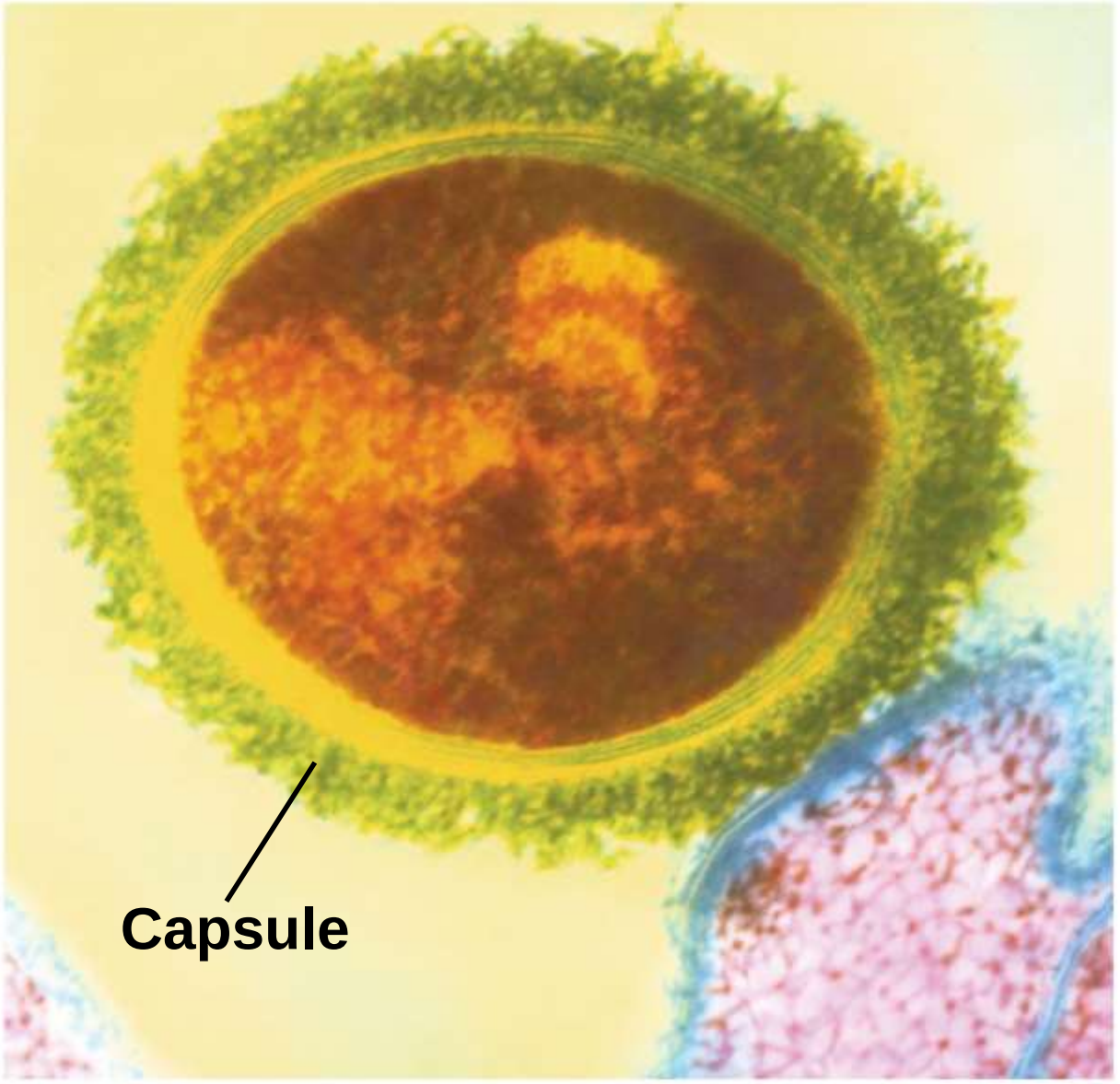




16.4 Various structural features contribute to the success of prokaryotes

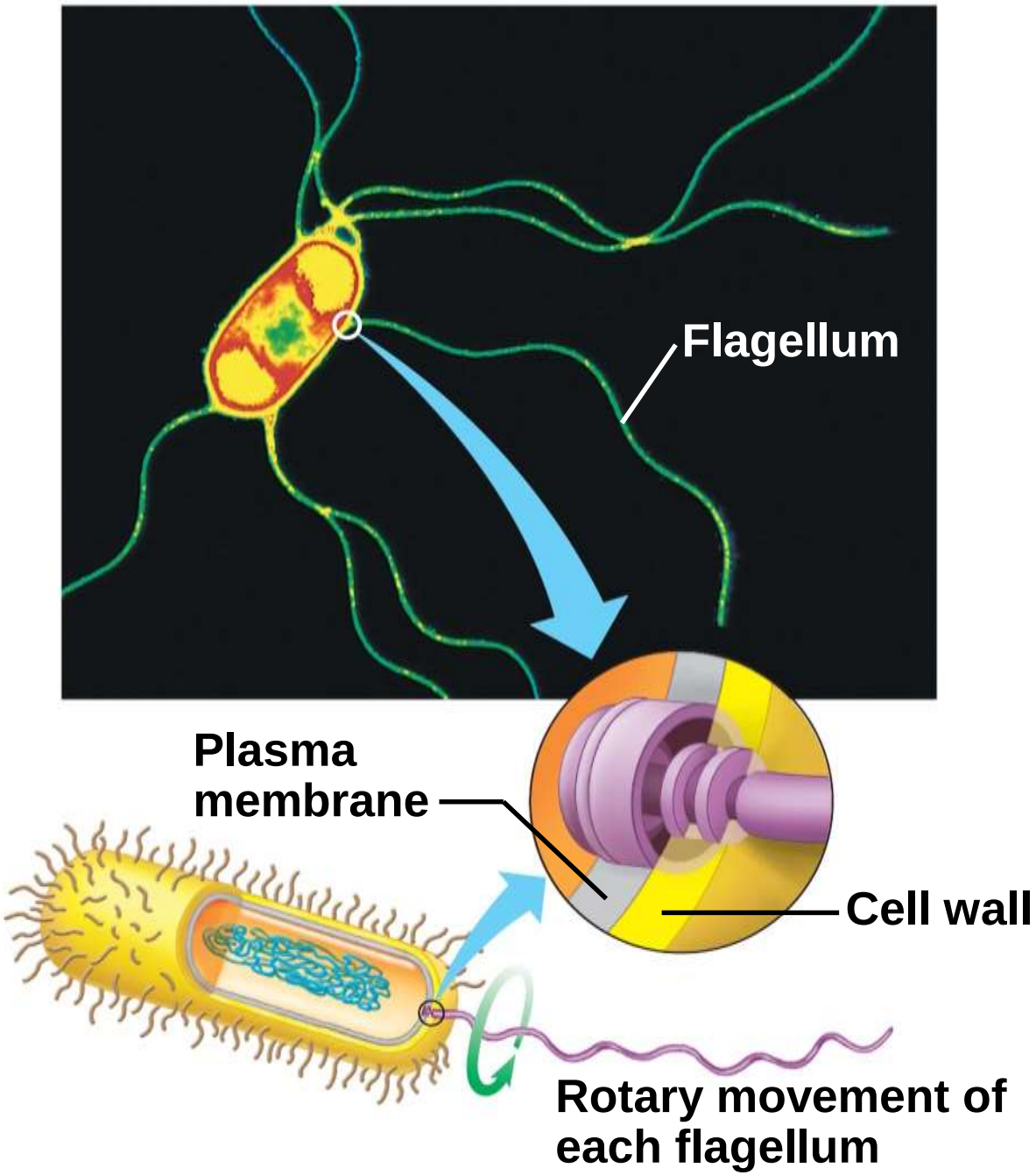
- Prokaryotic **cell walls** maintain cell shape, provide physical protection, and prevent the cell from bursting in a hypotonic environment
  - In a hypertonic environment, most prokaryotes lose water and shrink away from their wall
- The cell walls of Archaea and Bacteria differ

Video: Prokaryotic Flagella (*Salmonella typhimurium*)



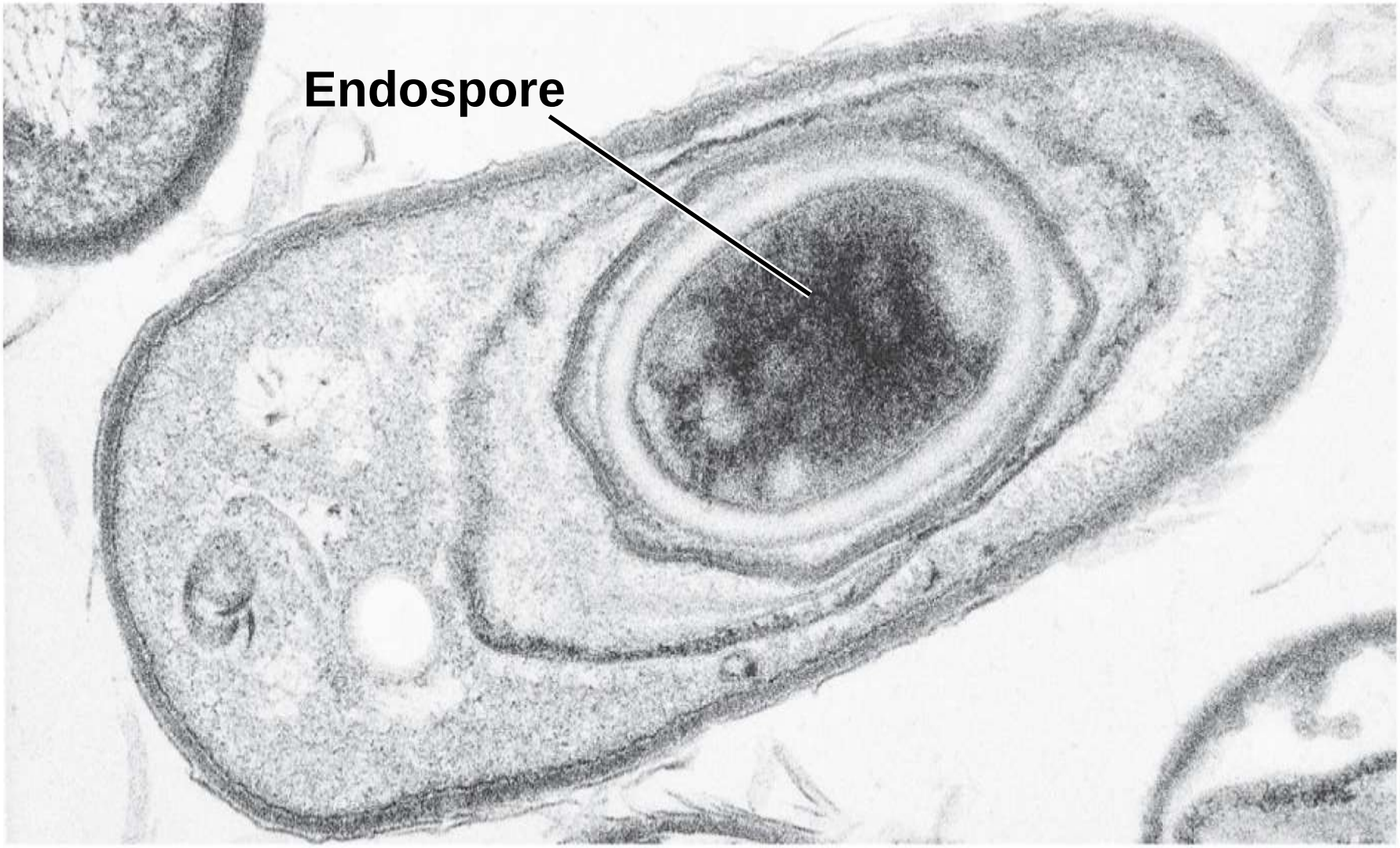
16.4 Various structural features contribute to the success of prokaryotes

- The **flagella** of Bacteria and Archaea allow them to move in response to chemical and physical signals in their environment
- The prokaryotic flagellum is a naked protein without microtubules
  - The flagellum rotates like a propeller



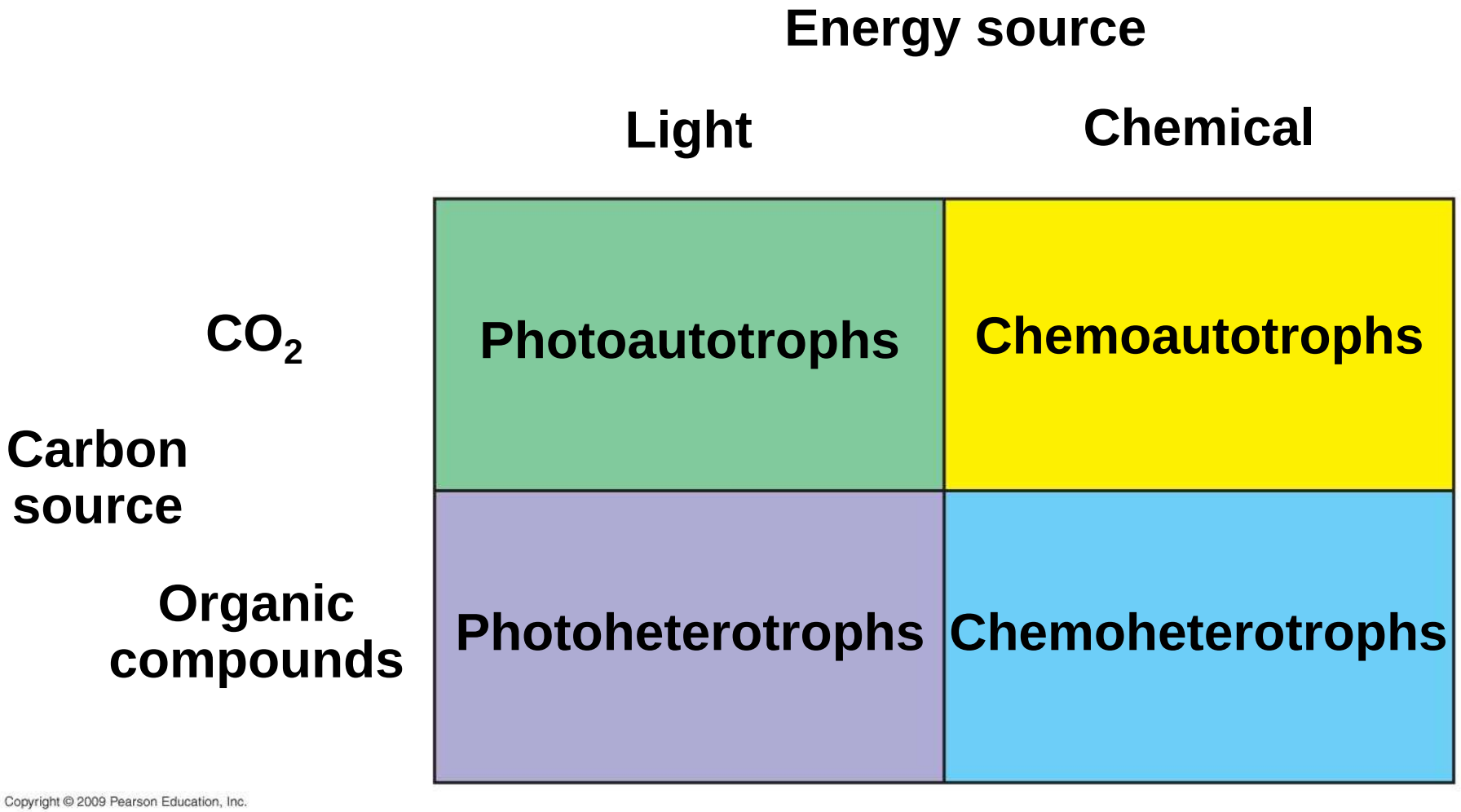
16.4 Various structural features contribute to the success of prokaryotes

- Some prokaryotes can withstand harsh conditions by forming **endospores** within an outer cell
  - The endospore has a thick protective coat
  - It can dehydrate and is tolerant of extreme heat or cold
- When conditions improve, the endospore absorbs water and resumes growth, sometimes after centuries



16.4 Various structural features contribute to the success of prokaryotes

- Prokaryotic DNA forms a circular chromosome
  - Smaller rings of DNA called **plasmids** carry genes that may provide resistance to antibiotics or metabolize rare nutrients, among other metabolic activities
- Many prokaryotes can transfer genes, such as antibiotic resistance genes, within or between species



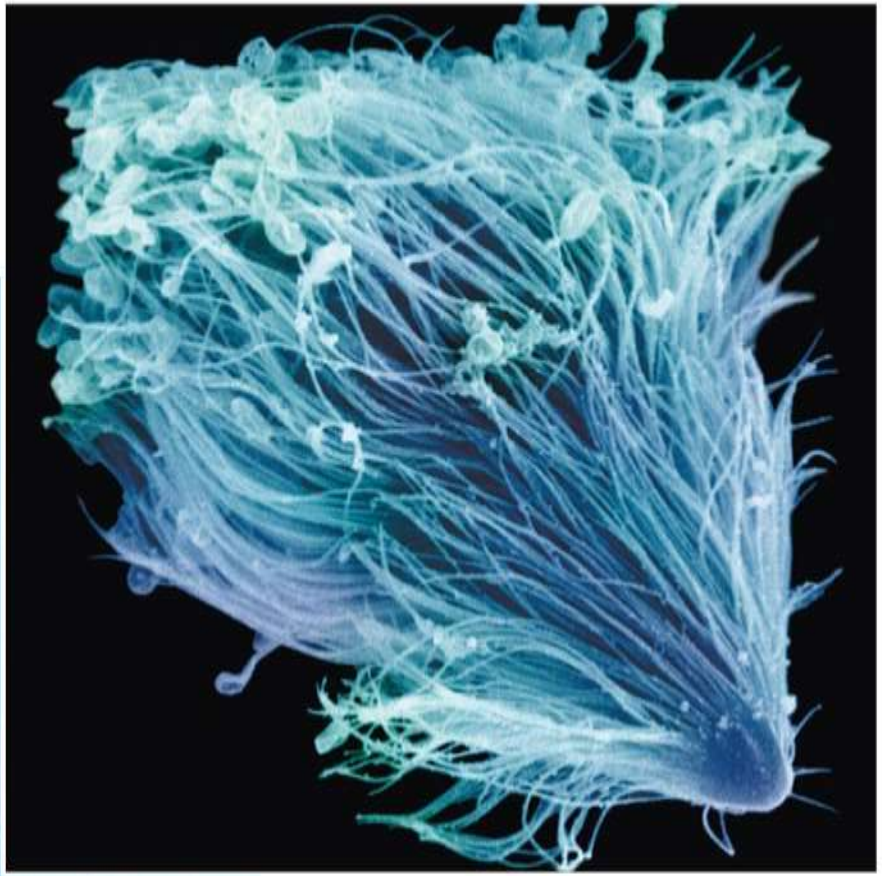
PROTISTS

16.11 Protists are an extremely diverse assortment of eukaryotes

- Protists constitute several kingdoms within the domain Eukarya
- Protists obtain their nutrition in a variety of ways
  - Algae are autotrophic protists
  - Protozoans are heterotrophic protists, eating bacteria and other protists
  - Fungus-like protists obtain organic molecules by absorption

16.11 Protists are an extremely diverse assortment of eukaryotes

- **Symbiosis** is a close association between organisms of two or more species
  - *Endo*symbiosis—living *within* another
  - Termite endosymbionts digest cellulose in the wood eaten by the host
  - The protists have endosymbiotic prokaryotes that metabolize the cellulose



16.11 Protists are an extremely diverse assortment of eukaryotes

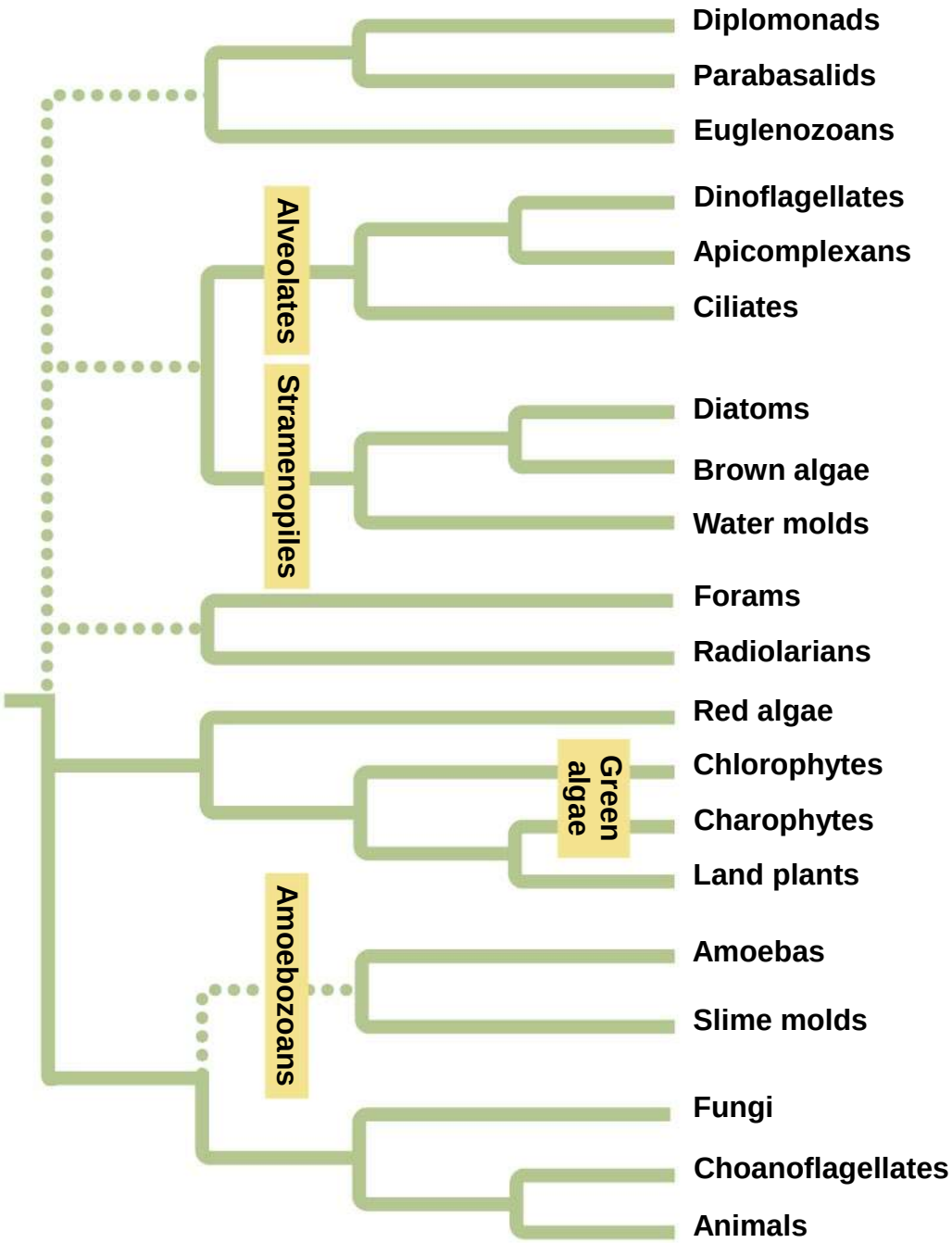
- Protists are eukaryotes, with
  - Membrane-bound chromosomes
  - Multiple chromosomes
  - Flagella or cilia with 9 + 2 pattern of microtubules
- Some protists have a very high level of cellular complexity

16.12 EVOLUTION CONNECTION: Secondary endosymbiosis is the key to protist diversity

- What is the origin of the enormous diversity of protists?
  - Complex eukaryotic cells evolved when prokaryotes took up residence within larger prokaryotes

16.13 A tentative phylogeny of eukaryotes includes multiple clades of protists

- The taxonomy of protists remains a work in progress
  - The names, boundaries, and placement of clades will continue to change as genomes of more protists are sequenced and compared



16.16 Alveolates have sacs beneath the plasma membrane

- **Alveolates** have membrane-enclosed sacs or alveoli beneath the plasma membrane
- **Dinoflagellates** are important members of marine and freshwater phytoplankton
  - Some live within coral animals, feeding coral reef communities
  - Dinoflagellate blooms cause red tides
- **Ciliates** use cilia to move and feed.
- **Apicomplexans** are animal parasites such as *Plasmodium*, which causes malaria

16.17 Stramenopiles have "hairy" and smooth flagella

- **Stramenopiles** are named for their "hairy" flagellum, usually paired with a "smooth" flagellum
  - **Water molds** are fungus-like and decompose dead organisms in freshwater habitats
  - **Diatoms** are unicellular, with silicate cell walls
  - **Brown algae** are large, complex algae called *seaweeds*; all are multicellular and most are marine

PLAY Video: Water Mold Oogonium

PLAY Video: Water Mold Zoospores

PLAY Video: Diatoms Moving

PLAY Video: Various Diatoms

16.18 Amoebozoans have lobe-shaped pseudopodia

- Amoebas move and feed by means of **pseudopodia**
- Members of the clade **amoebozoans** include many free-living amoebas, some parasitic amoebas, and slime molds
  - All have lobe-shaped pseudopodia

PLAY Video: Amoeba

PLAY Video: Amoeba Pseudopodia

PLAY Video: Plasmodial Slime Mold Streaming

PLAY Video: Plasmodial Slime Mold Zoom

16.20 Red algae and green algae are the closest relatives of land plants

- **Red algae** are typically soft-bodied, but some have cell walls encrusted with hard, chalky deposits
- **Green algae** split into two groups, the chlorophytes and the charophytes
  - The charophytes are the closest living relatives of land plants

16.21 EVOLUTION CONNECTION: Multicellularity evolved several times in eukaryotes

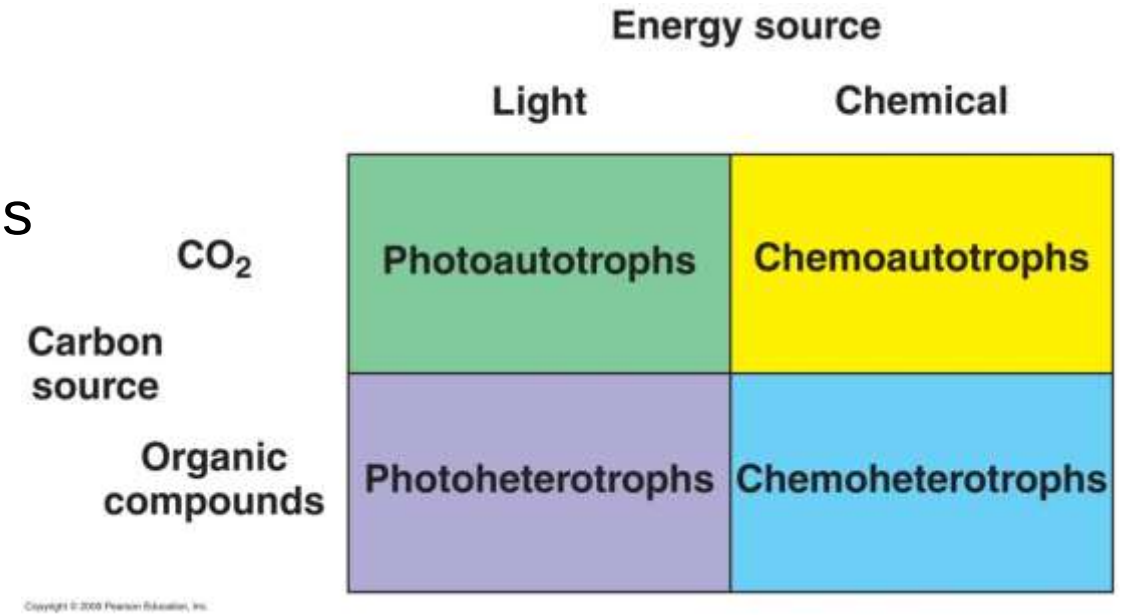
- Multicellularity evolved in several different lineages, probably by specialization of the cells of colonial protists.
  - Stramenopile lineage → brown algae
  - Unnamed lineage → red algae, green algae, land plants
  - Opisthokont lineage → fungi and animals
- Multicellular life arose over a billion years ago.
- By 543 million years ago, diverse animals and multicellular algae lived in aquatic environments; plants and fungi colonized land 500 million years ago

Nutritional Mode	Energy Source	Carbon Source
Photoautotroph	Sunlight	CO_2
Chemoautotroph	Inorganic chemicals	
Photoheterotroph	Sunlight	Organic compounds
Chemoheterotroph	Organic compounds	

Concept Check

Prokaryote's modes of nutrition are more diverse than eukaryotes—they have more ways to make a living. Nutrition provides two main resources: energy and carbon for building compounds. What source of energy do photoautotrophs and photoheterotrophs exploit as their primary source of energy?

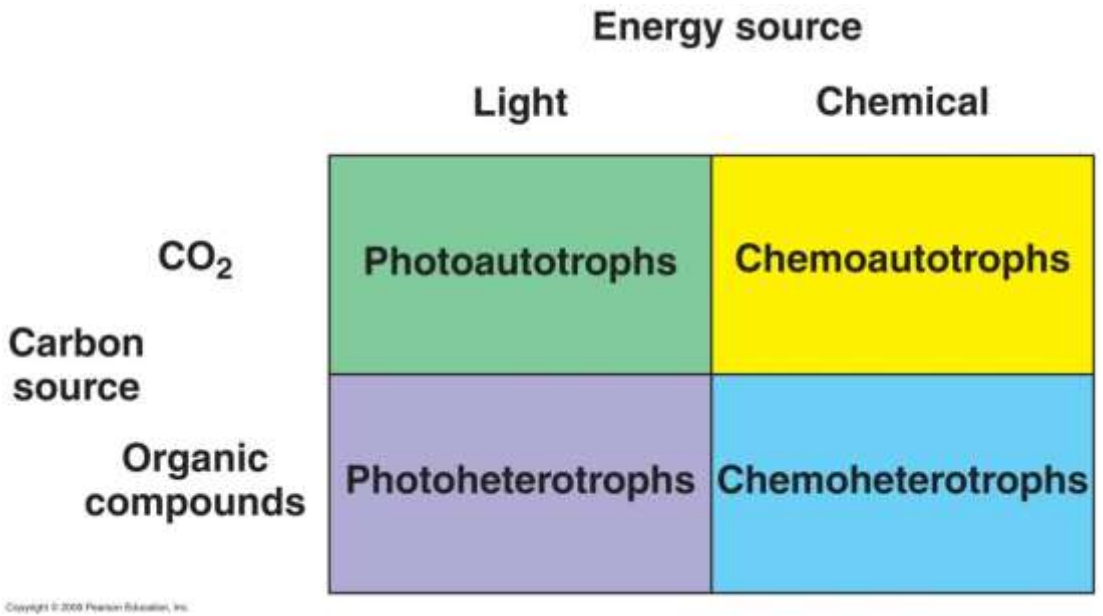
1) Chemical
2) Light
3) Organic compounds
4) Carbon dioxide



Answer

Prokaryote's modes of nutrition are more diverse than eukaryotes—they have more ways to make a living. Nutrition provides two main resources: energy and carbon for building compounds. What source of energy do photoautotrophs and photoheterotrophs exploit as their primary source of energy?

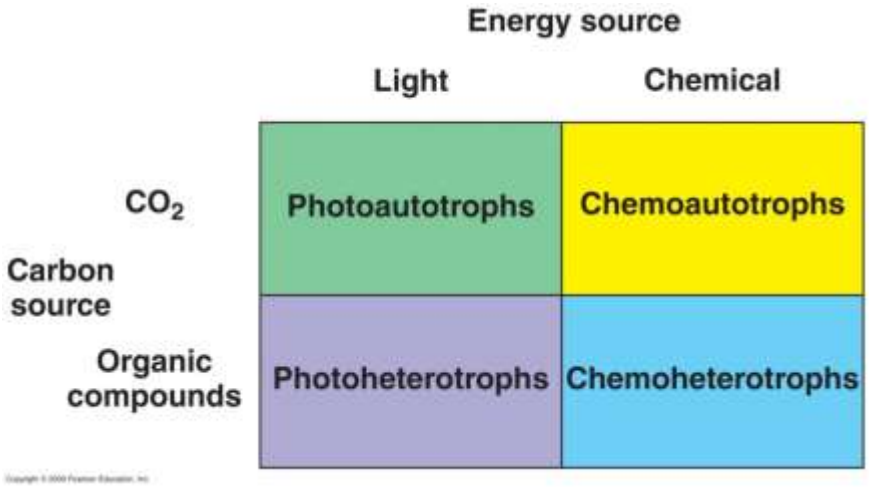
2) Light



Concept Check

Which of the following describe one of the differences between heterotrophs and autotrophs?

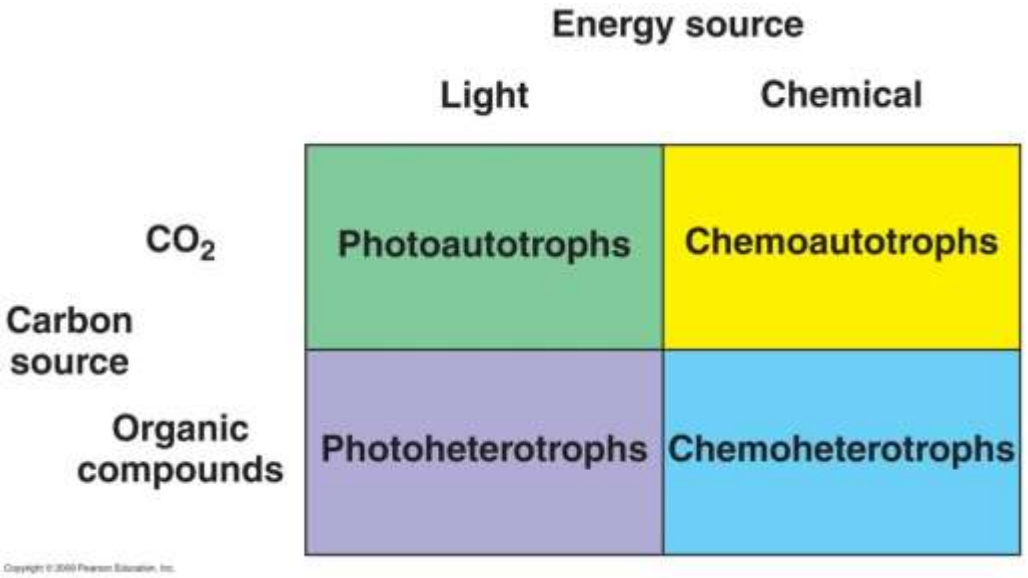
1) Autotrophs use organic compounds as an carbon source.
2) Autotrophs use inorganic compounds as an carbon source.
3) Autotrophs use sunlight as an carbon source.
4) Autotrophs use carbon dioxide as an carbon source.



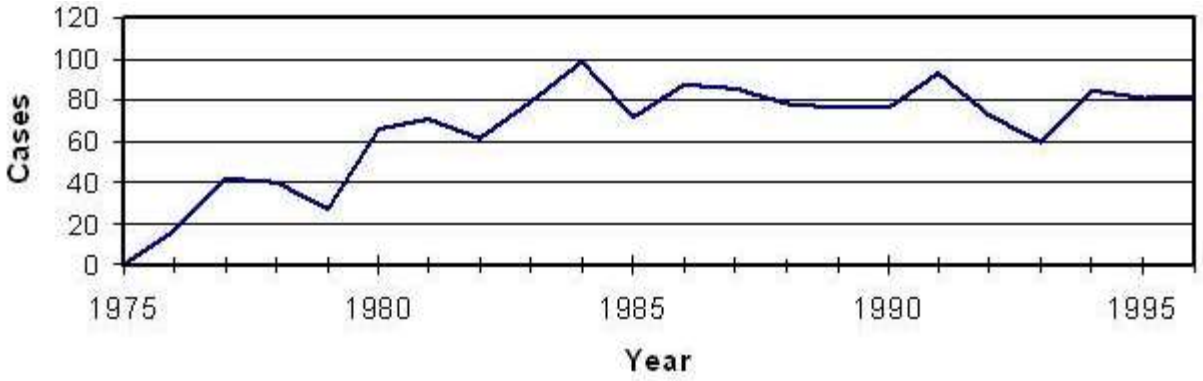
Answer

Which of the following describe one of the differences between heterotrophs and autotrophs?

4) Autotrophs use carbon dioxide as an carbon source.



Thinking like a scientist

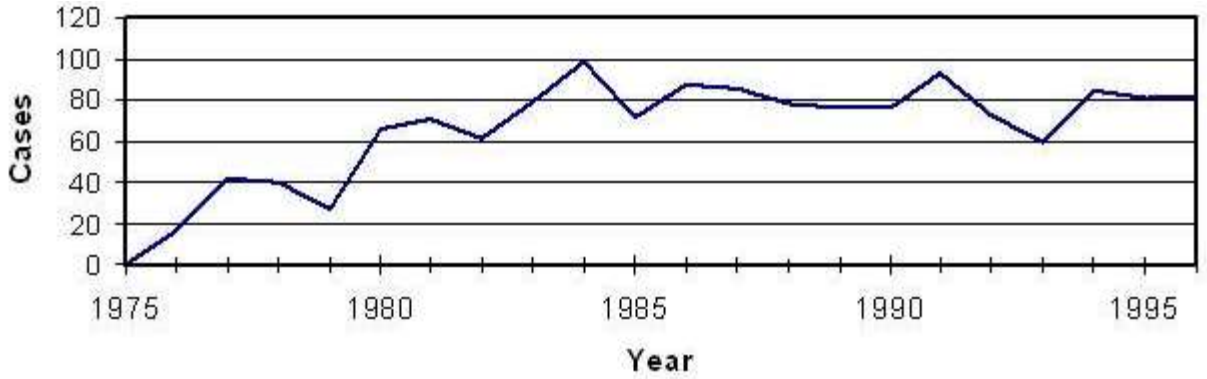


Botulism in the United States, 1899-1996, Handbook for Epidemiologists, Clinicians, and Laboratory Workers. Centers for Disease Control and Prevention Division of Bacterial and Mycotic Diseases, 1998.

Infant botulism was first recognized in 1976. *Clostridium botulinum* bacteria are ingested and colonize the infants intestine. There, the *C. botulinum* produce the toxin that results in the disease. From this graph which of the following is a valid conclusion?

1) Infant botulism is a rapidly growing disease.
2) The annual occurrence of the disease is fairly constant.
3) The disease is in decline.
4) This is a common disease.

Answer



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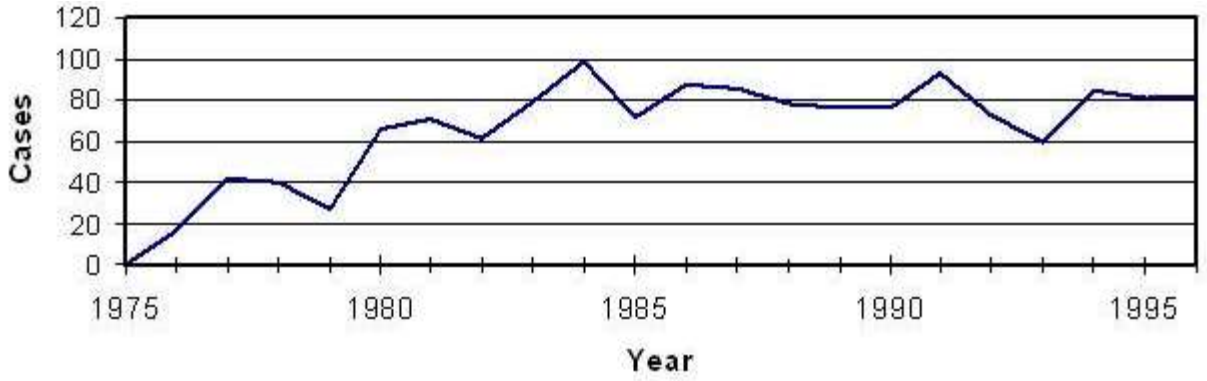

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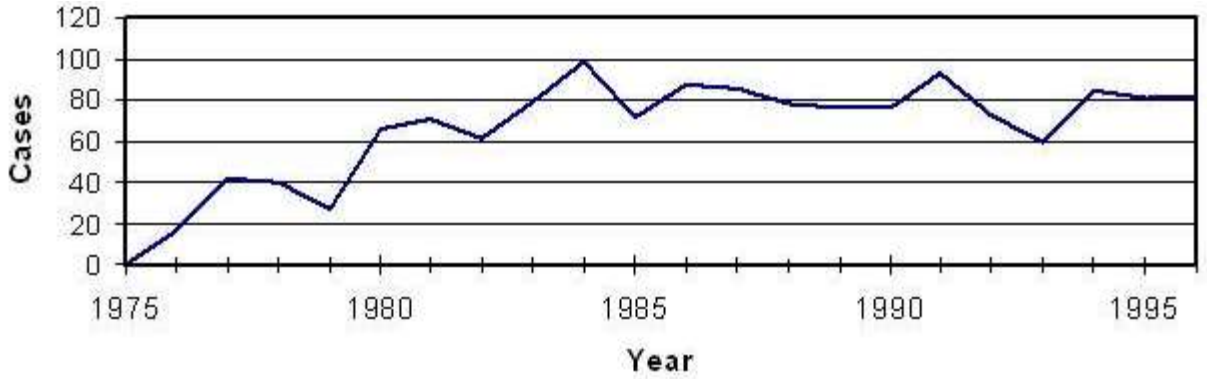
The rate of infection has stabilized to about 1.9 cases per 100,000 births in the U.S. (CDC) However, the rates for for states is much higher: Delaware, 9.0; Hawaii, 8.8; Utah, 6.3; and California at 5.7 per 100,000 births. Which state accounts for 47% of all infant botulism cases?

1) Delaware
2) Hawaii
3) Utah
4) California

Answer



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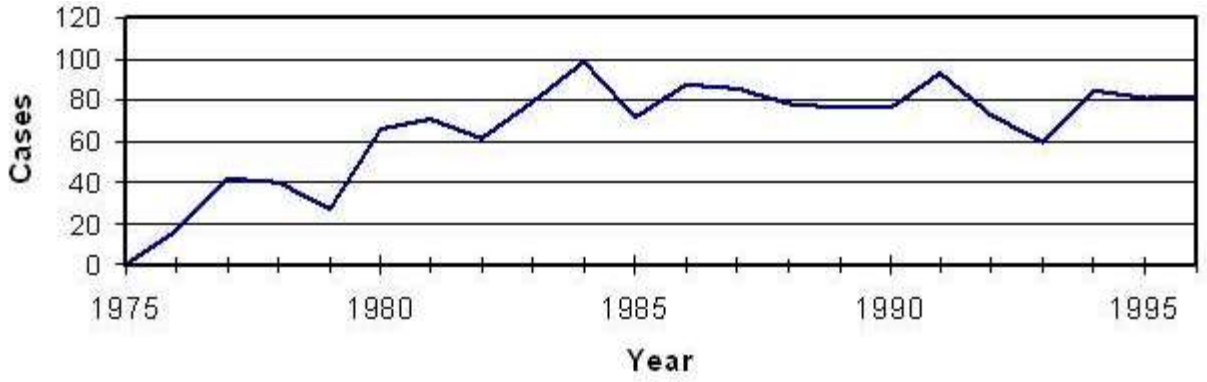

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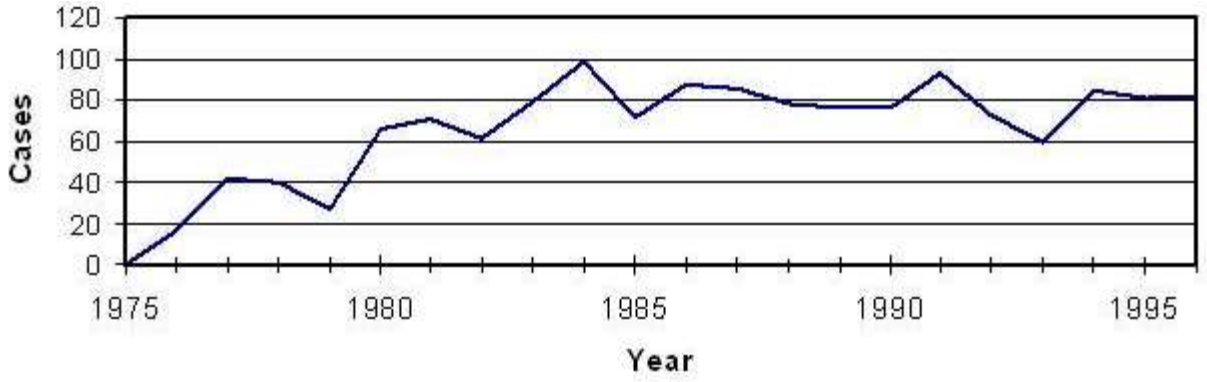
In 2001-2002 four cases of infant botulism were reported in Staten Island, New York. Is this rate of infection significantly higher than normal?

1) Yes
2) No
3) Not enough information

Answer



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1) Yes

Science and Society

Today, biology is considered a growth field—ripe for new opportunities for employment and business. And it is not just the development of biotechnology. The use of biological weapons by terrorists groups has increased the demand for research into countering such weapons. As a biology student, do you think that biological warfare is an appropriate topic for study?

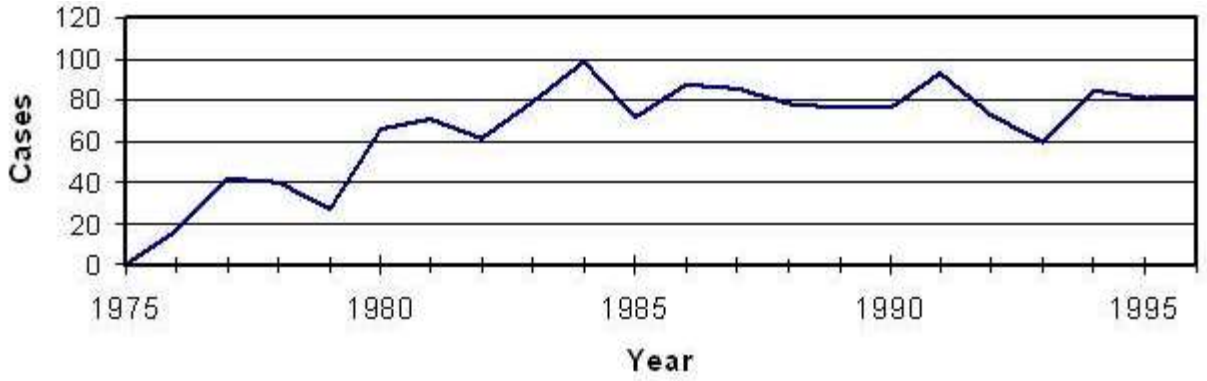
Strongly Disagree **A** **B** **C** **D** **E** **Strongly Agree**

Science and Society

For fifty years, scientists have conducted a number of laboratory experiments that attempt to define the conditions that may have led to the origin of life on earth. Do you think that trying to recreate life in the laboratory similar to early life on earth is appropriate research?

Strongly Disagree **A** **B** **C** **D** **E** **Strongly Agree**

Science and Society



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At the time of this publication the risk factors for the disease Infant botulism are not well characterized. However, in some studies 20% of the infants apparently ingested spores from *C. botulinum* from honey. The CDC recommends that infants (less than 1 year old) not be fed honey. Do you think that the CDC recommendation is appropriate?

Strongly Disagree **A** **B** **C** **D** **E** **Strongly Agree**