CH 16: Microbial Life: Prokaryotes and Protists

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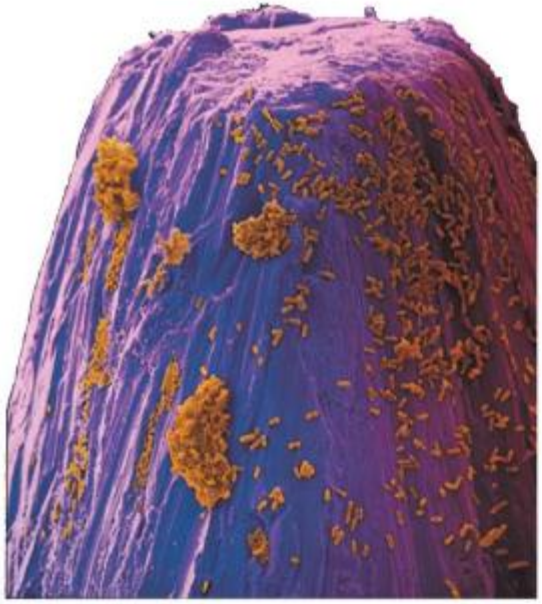
Human microbiome: your birthday gift

- https://www.youtube.com/watch?v=YB0WDp-Stys

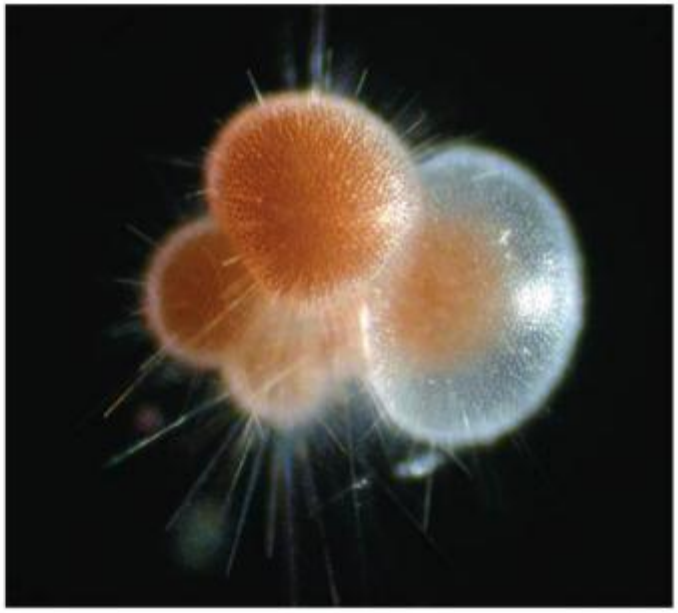
- E. coli food poisoning?
  - Right strain in the right location

Figure 16.0-2

Chapter 16: Big Ideas



Prokaryotes

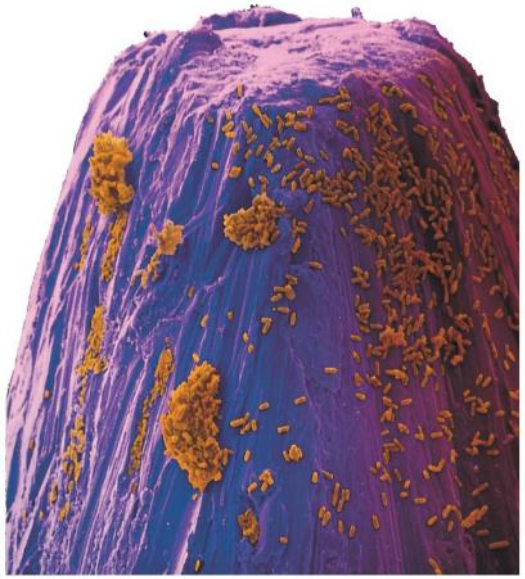


Protists

PROKARYOTES

16.1 Prokaryotes are diverse and widespread

- Prokaryotic cells are smaller than eukaryotic cells.
  - Prokaryotes range from 1 to 5 μm in diameter.
  - Eukaryotes range from 10 to 100 μm in diameter.
- The collective biomass of prokaryotes is at least 10 times that of all eukaryotes.



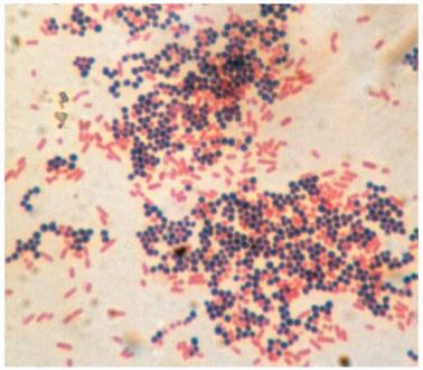
16.1 Prokaryotes are diverse and widespread

- Our **microbiota** consists of the community of microorganisms that live in and on our bodies.
- Each of us harbors several hundred different species and genetic strains of prokaryotes, including a few whose positive effects are well studied.
  - Some intestinal bacteria supply essential vitamins and enable us to extract nutrition from food molecules that we can't otherwise digest.
  - Many of the bacteria that live on our skin perform helpful housekeeping functions such as decomposing dead skin cells.
  - Other prokaryotes guard against pathogenic intruders.

Figure 16.2a-0

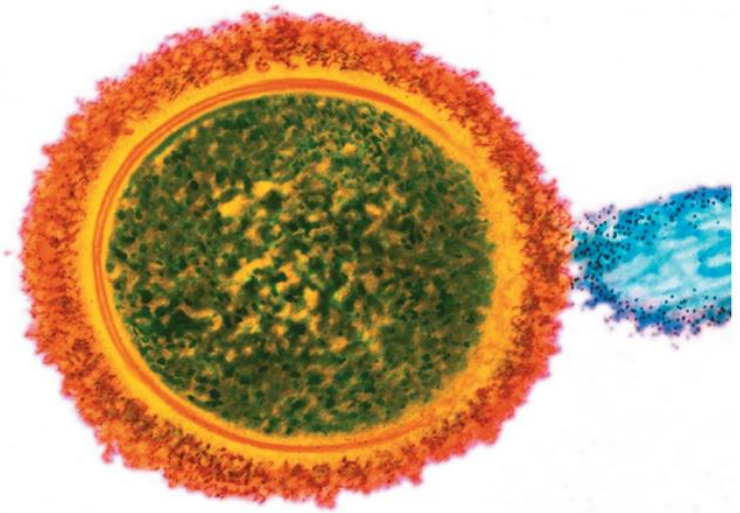
16.2 External features contribute to the success of prokaryotes

- Nearly all prokaryotes have a cell wall.
- When stained with **Gram stain**, cell walls of bacteria are either
  - gram-positive, with simpler cell walls containing **peptidoglycan (“月太”聚糖)**
  - gram-negative, with less peptidoglycan. More complex and more likely to cause disease.
  - Graph: purple = positive
    pink = negative



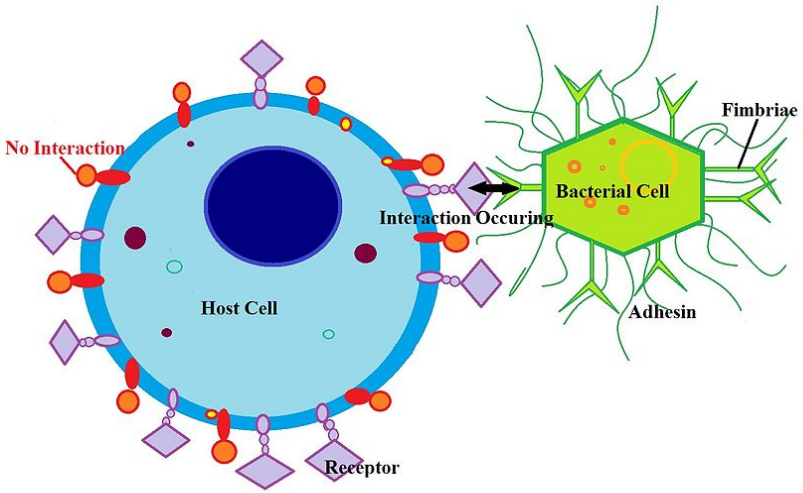
16.2 External features contribute to the success of prokaryotes

- The cell wall of many prokaryotes is covered by a capsule, a sticky layer of polysaccharides or protein.
- The capsule
  - enables prokaryotes to adhere to something
  - shields pathogenic prokaryotes from attacks by their host's immune system.

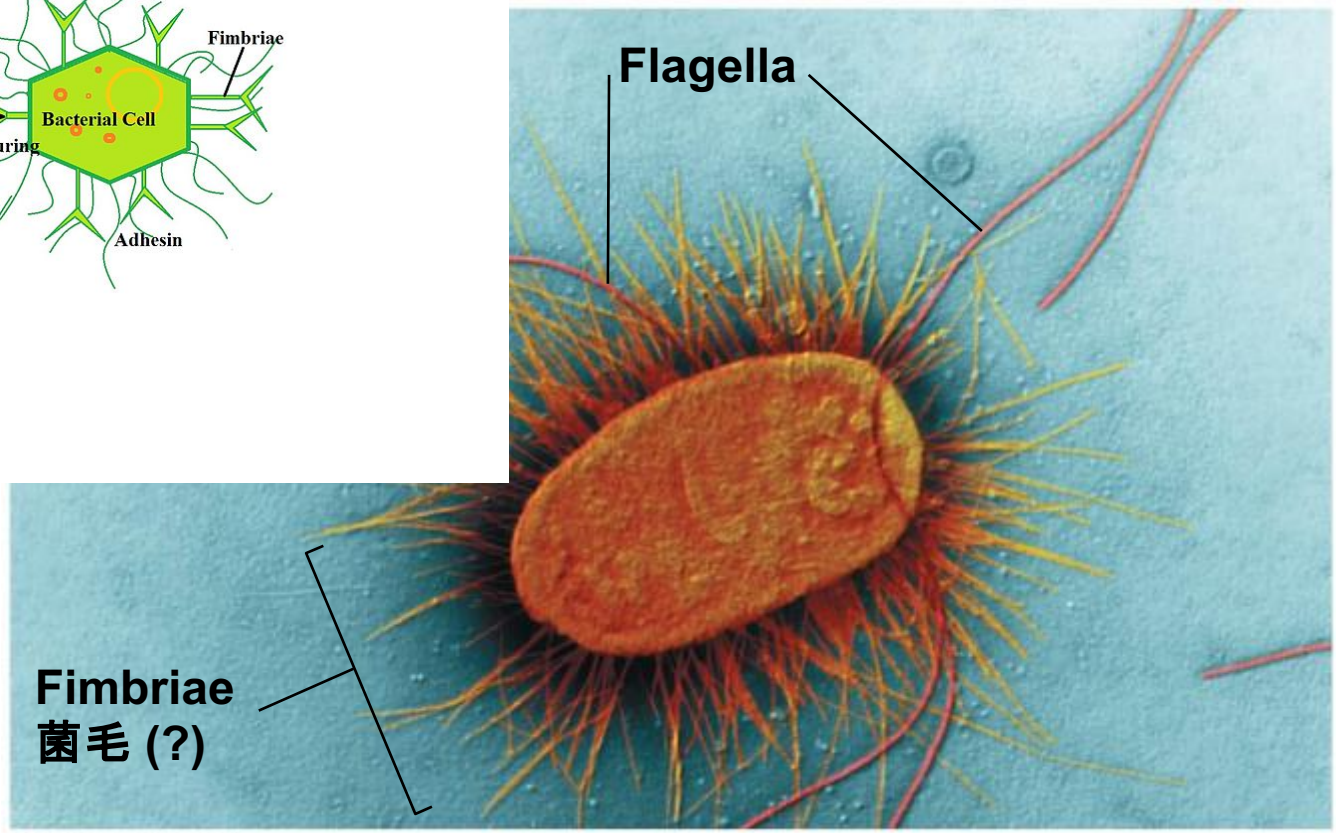


16.2 External features contribute to the success of prokaryotes

- Some prokaryotes have external structures that extend beyond the cell wall.



Wikipedia

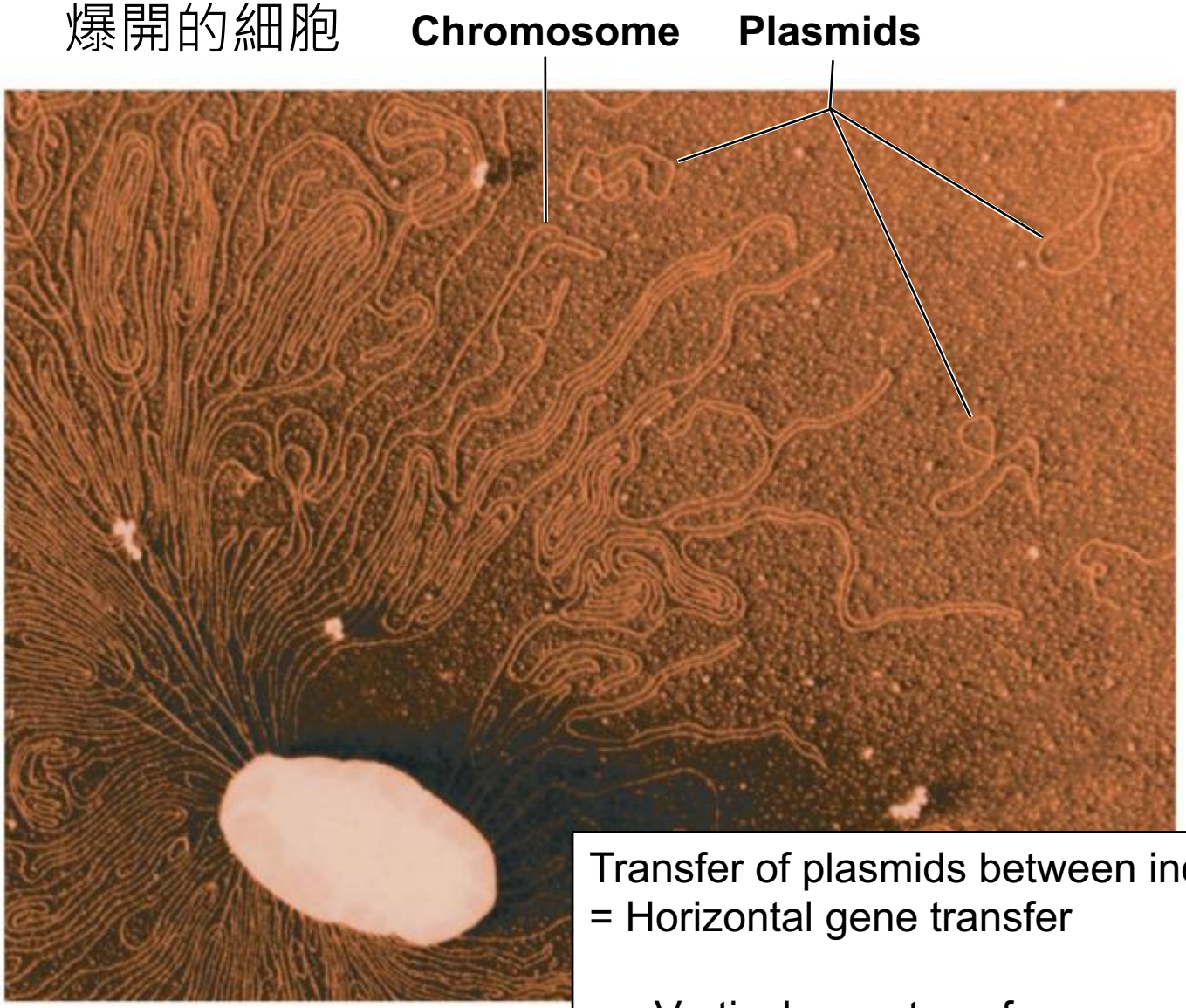


16.3 Populations of prokaryotes can adapt rapidly to changes in the environment

- The genome of a prokaryote typically
  - has about one-thousandth as much DNA as a eukaryotic genome and
  - is one long, circular chromosome packed into a distinct region of the cell.
- Many prokaryotes also have additional small, circular DNA molecules called plasmids (質體), which replicate independently of the chromosome.

Figure 16.3a

爆開的細胞



Transfer of plasmids between individuals
= Horizontal gene transfer

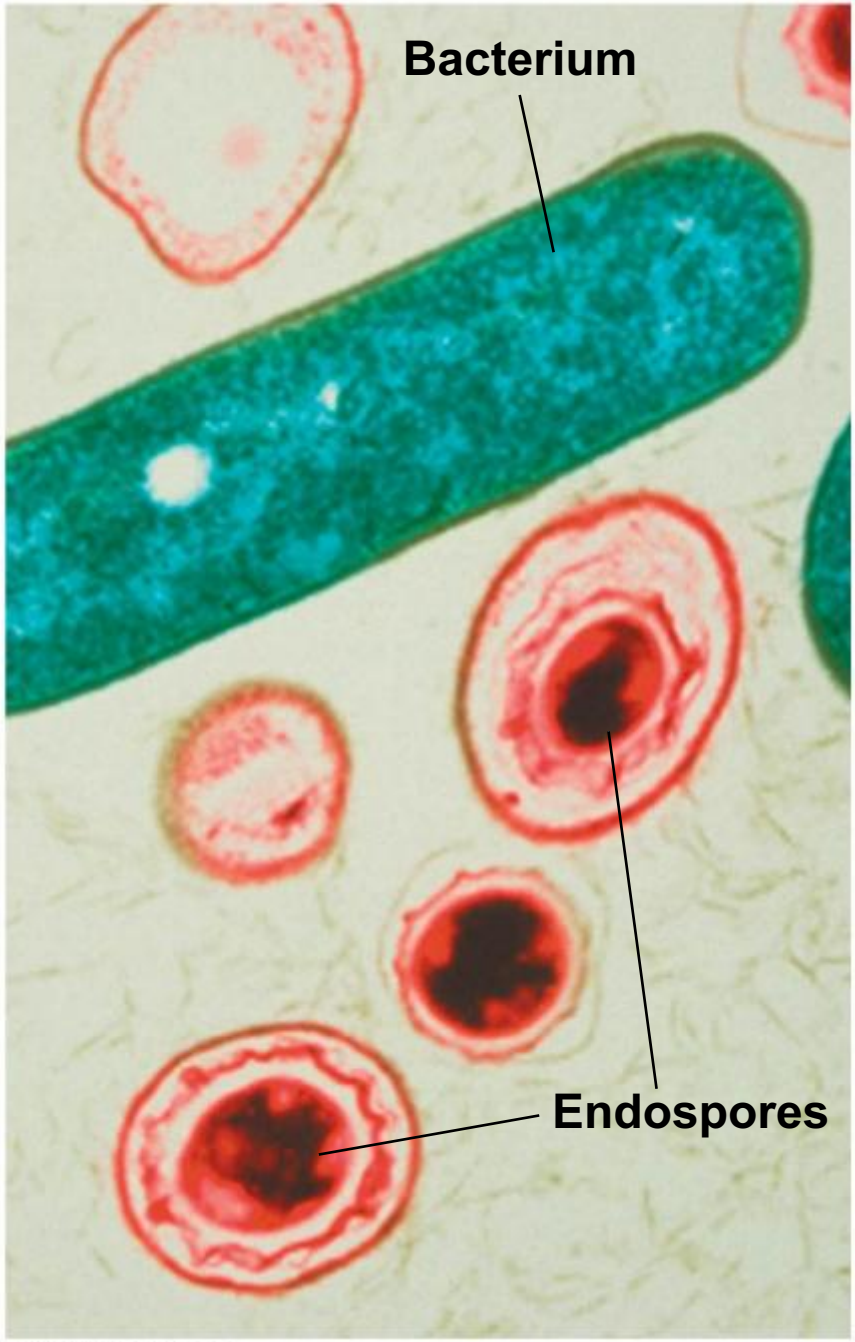
vs. Vertical gene transfer

https://www.youtube.com/watch?v=GNMJBMtKKWU

16.3 Populations of prokaryotes can adapt rapidly to changes in the environment

- Some prokaryotes form specialized cells called **endospores** that remain dormant through harsh conditions.
- Endospores can survive extreme heat or cold.
- When the endospore receives environmental cues that conditions have improved, it
  - absorbs water and
  - resumes growth.

Figure 16.3b

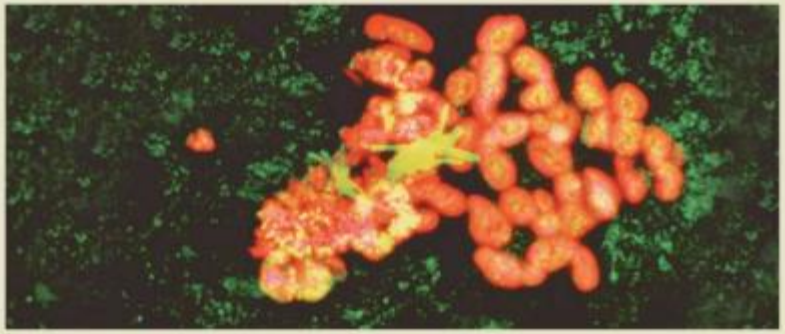


16.4 Prokaryotes have unparalleled nutritional diversity

- Two sources of energy are used.
  1. *Phototrophs* capture energy from sunlight.
  2. *Chemotrophs* harness the energy stored in chemicals.

- Two sources of carbon are used by prokaryotes.
  - **Autotrophs** obtain carbon atoms from carbon dioxide.
  - **Heterotrophs** obtain their carbon atoms from the organic compounds present in other organisms.

Figure 16.4-0

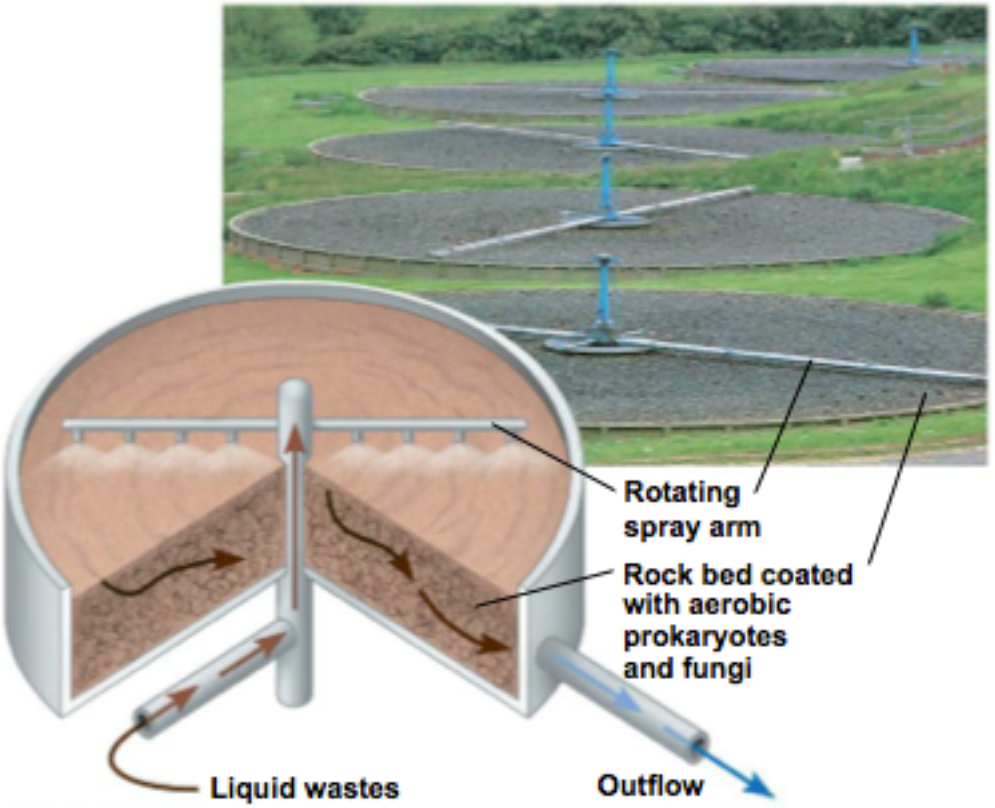
		ENERGY SOURCE	
		Sunlight	Chemicals
CARBON SOURCE	CO_2	Photoautotrophs  *Oscillatoria*	Chemoautotrophs  Unidentified “rock-eating” bacteria
	Organic compounds	Photoheterotrophs  *Rhodopseudomonas*	Chemoheterotrophs  *Salmonella typhimurium*

16.5 CONNECTION: Biofilms are complex associations of microbes

- **Biofilms** are highly organized colonies that attach to surfaces.
- Biofilms consist of one or several species of prokaryotes and may also include protists and fungi.

16.6 CONNECTION: Prokaryotes help clean up the environment

- **Bioremediation** is the use of organisms to remove pollutants from
  - soil,
  - air, or
  - water.

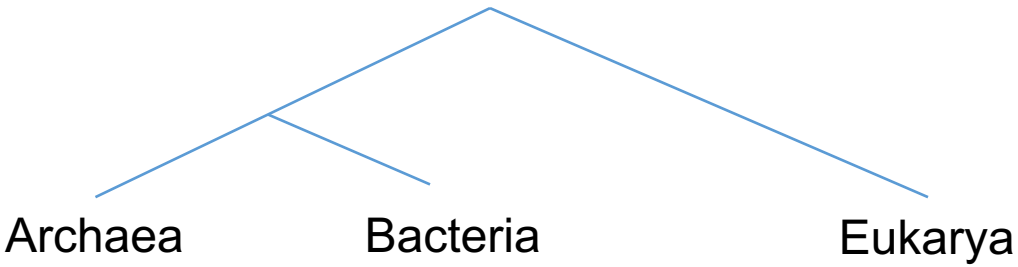


16.7 Bacteria and archaea are the two main branches of prokaryotic evolution

- New studies of representative genomes of prokaryotes and eukaryotes strongly support the three-domain view of life.
  - Eukaryotes belong to the domain Eukarya.
  - Prokaryotes are now classified into two domains:
    1. Bacteria and
    2. Archaea.

Table 16.7

If we only use “has cell nucleus or not”



If we only use many other traits

TABLE 16.7 | DIFFERENCES BETWEEN THE DOMAINS BACTERIA, ARCHAEA, AND EUKARYA

Characteristic	Bacteria	Archaea	Eukarya
rRNA sequences	Some unique to bacteria	Some unique to archaea; some match eukaryotic sequences	Some unique to eukaryotes; some match archaeal sequences
RNA polymerase	One kind; relatively small and simple	Several kinds; complex	Several kinds; complex
Introns	Rare	In some genes	Present
Peptidoglycan in cell wall	Present	Absent	Absent
Histones associated with DNA	Absent	Present in some species	Present

This is also supported by molecular phylogeny

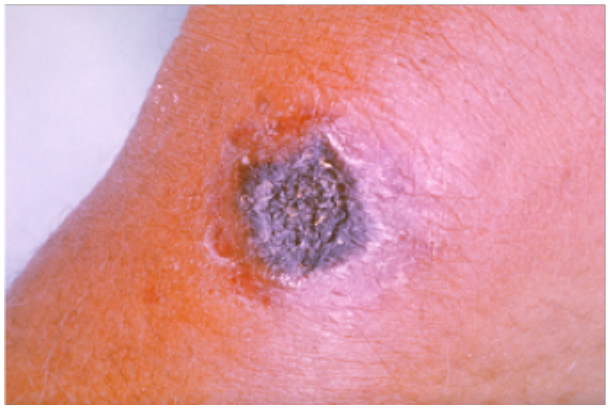
16.8 Archaea thrive in extreme environments—and in other habitats

- Archaeal inhabitants of extreme environments have unusual proteins and other molecular adaptations that enable them to metabolize and reproduce effectively.
  - **Extreme halophiles** thrive in very salty places.
  - **Extreme thermophiles** thrive in
    - very hot water, such as geysers, and
    - acid pools.

16.10 CONNECTION: Some bacteria cause disease

- *Bacillus anthracis* (炭疽菌) forms hardy endospores that have been used as biological weapons.

北韓變節士兵有炭疽桿菌抗體| 蘋果日報
https://tw.appledaily.com/international/daily/20171228/37886771 ▾ Translate this page
Dec 28, 2017 - 【陳怡姣／綜合外電報導】南韓「Channel A」電視台前天引述情報官員報導，今年叛逃到南韓的4名北韓士兵當中，有1名被驗出體內有炭疽桿菌抗體，似乎印證北韓正在研發高致命性的炭疽桿菌武器傳聞。另南韓統一部昨公布30名脫北者核輻射調查的結果，有4人驗出曾暴露於輻射線，但不確定是否和北韓核試有關。



Wiki

SCIENTIFIC AMERICAN 科學人雜誌

環境與生態

永凍土驚爆病菌危機

正在解凍的永凍土區塊越來越大，釋出原本深埋其中的致病微生物。

撰文／古達奇（Sara Goudarzi）
翻譯／王心瑩

TechNews 科技新報

冰封多年傳染病因暖化開始現身，俄國極圈爆發炭疽病

作者 地球圖輯隊 | 發布日期 2016 年 08 月 06 日 0:00 | 分類 環境科學

16.10 CONNECTION: Some bacteria cause disease

- The weapon form of *C. botulinum* (肉毒桿菌) is the exotoxin it produces, botulinum, which is the deadliest poison known.
- Botulinum blocks transmission of the nerve signals that cause muscle contraction, resulting in paralysis of the muscles required for breathing.
- This effect is also responsible for a more benign use of botulinum—relaxing facial muscles that cause wrinkles.

Figure 16.10b

16.10 CONNECTION: Some bacteria cause disease

- Plague (black death)
- Bacterium *Yersinia pestis*
- Spread by rat flea ?
  From the east into Europe.

- https://technews.tw/2018/02/05/black-death-spread-by-human-fleas-and-lice/
- Google: 蒙古, 投石車, 黑死病

16.11 SCIENTIFIC THINKING: Stomach microbiota affect health and disease

- For a human disease, the researcher must:

1. find the candidate bacterium in every case of the disease;
2. isolate the bacterium and grow it in pure culture;
3. show that the cultured bacterium causes the disease when transferred to a healthy subject (usually an animal);
4. isolate the bacterium from the experimentally infected subject.

16.11 SCIENTIFIC THINKING: Stomach microbiota affect health and disease

- Australian microbiologist Barry Marshall hypothesized that chronic gastritis (慢性胃炎, an inflammation of the stomach lining that can lead to ulcers 胃潰瘍) was caused by a bacterium *Helicobacter pylori*.
  - Over the course of several years, Marshall satisfied the first two requirements, but his efforts to infect animals failed to produce results.
  - At last, Marshall decided to take a radical course of action—he would experiment on himself.
  - He swallowed *H. pylori*

16.11 SCIENTIFIC THINKING: Stomach microbiota affect health and disease

- Several days later, he became ill from gastritis (step 3).
- His stomach lining proved to be teeming with *H. pylori* (step 4). Marshall then cleared up his infection with antibiotics.
- He continued to make progress in his research, and other scientists followed up with further studies.
- Several years later, antibiotics became a standard treatment for ulcer patients.

Figure 16.11a

Gut microbiome is associated with our health

- Associated with BMI
- Associated with health and disease
- Athletes have different microbiome vs. others

「吃屎」可以減肥？這些微生物基因測序公司沒開玩笑- 每日頭條
https://kknews.cc › 科學
Sep 7, 2016 - 你以為你每天克制飲食，勤於鍛鍊，就一定會瘦嗎？ 實驗證明，與其刻苦減肥，不如「吃屎」。 2009 年，美國微生物科學院院士、上海交大教授趙立平通過微生物基因組測序技術，證實肥胖與雙歧桿菌減少、硫酸鹽還原菌增加正相關。為了改變胖子的腸道菌群，美國麻省總醫院研發了一種「有味道」 的技術：把瘦子的糞便 ...

But remember: correlation is not causation

More on human microbiome

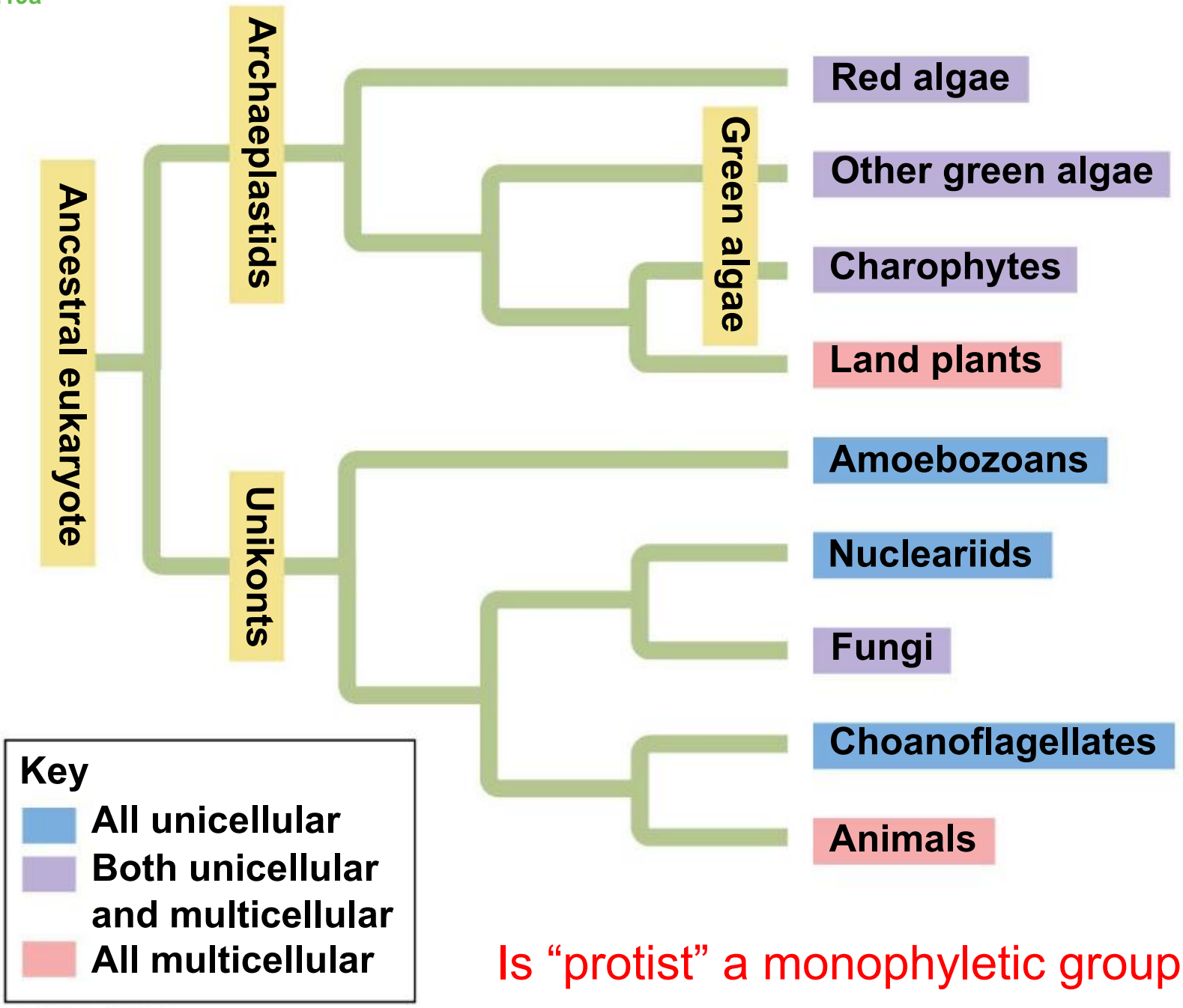
- https://www.youtube.com/watch?v=VzPD009qTN4
- Even related with lactose intolerant (乳糖不耐症)
  - Babies produce lactase (乳糖酶), an enzyme the helps digest lactose.
  - Many adults cannot produce lactase anymore.
  - In the human history, an allele that enables adults to produce lactase is strongly favored by natural selection: the strongest signal of directional selection in the human genome (not in Asians).
  - Both genetics (lactase allele) and environment (gut microbiome) – The story of my European friend.

PROTISTS

16.12 Protists are an extremely diverse assortment of eukaryotes

- **Protists**
  - mostly unicellular eukaryotes,
  - refer to eukaryotes that are not
    - plants,
    - animals, or
    - fungi.

Figure 16.19a



Is “protist” a monophyletic group?

Figure 16.12a-0

Autotrophy

***Caulerpa*, a green alga**

Heterotrophy

***Giardia*, a parasite**

Mixotrophy

Euglena

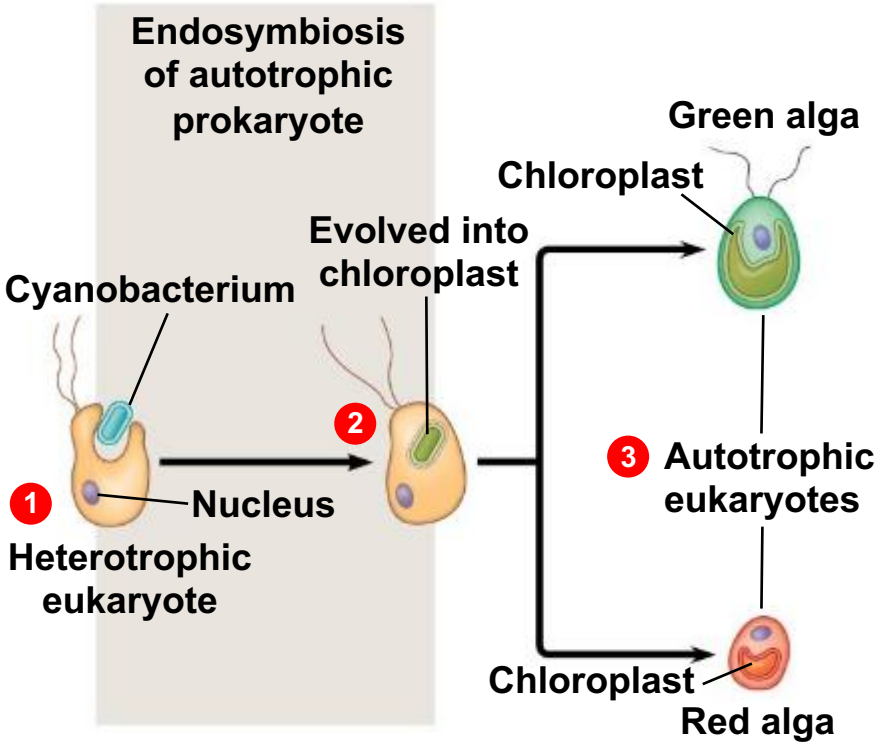
16.13 EVOLUTION CONNECTION: Endosymbiosis of unicellular algae is the key to much of protist diversity

- The endosymbiont theory explains the origin of mitochondria and chloroplasts.
  - According to this theory, oxygen-using prokaryotes established residence within other, larger prokaryotes.
  - These endosymbionts evolved into mitochondria, giving rise to heterotrophic eukaryotes.

16.13 EVOLUTION CONNECTION: Endosymbiosis of unicellular algae is the key to much of protist diversity

- Autotrophic eukaryotes later arose through **primary endosymbiosis**:
  1. A heterotrophic eukaryote engulfed an autotrophic cyanobacterium.
  2. Over time, the descendants of the original cyanobacterium evolved into chloroplasts.
  3. The chloroplast-bearing lineage of eukaryotes later diversified into the autotrophs green algae and red algae.

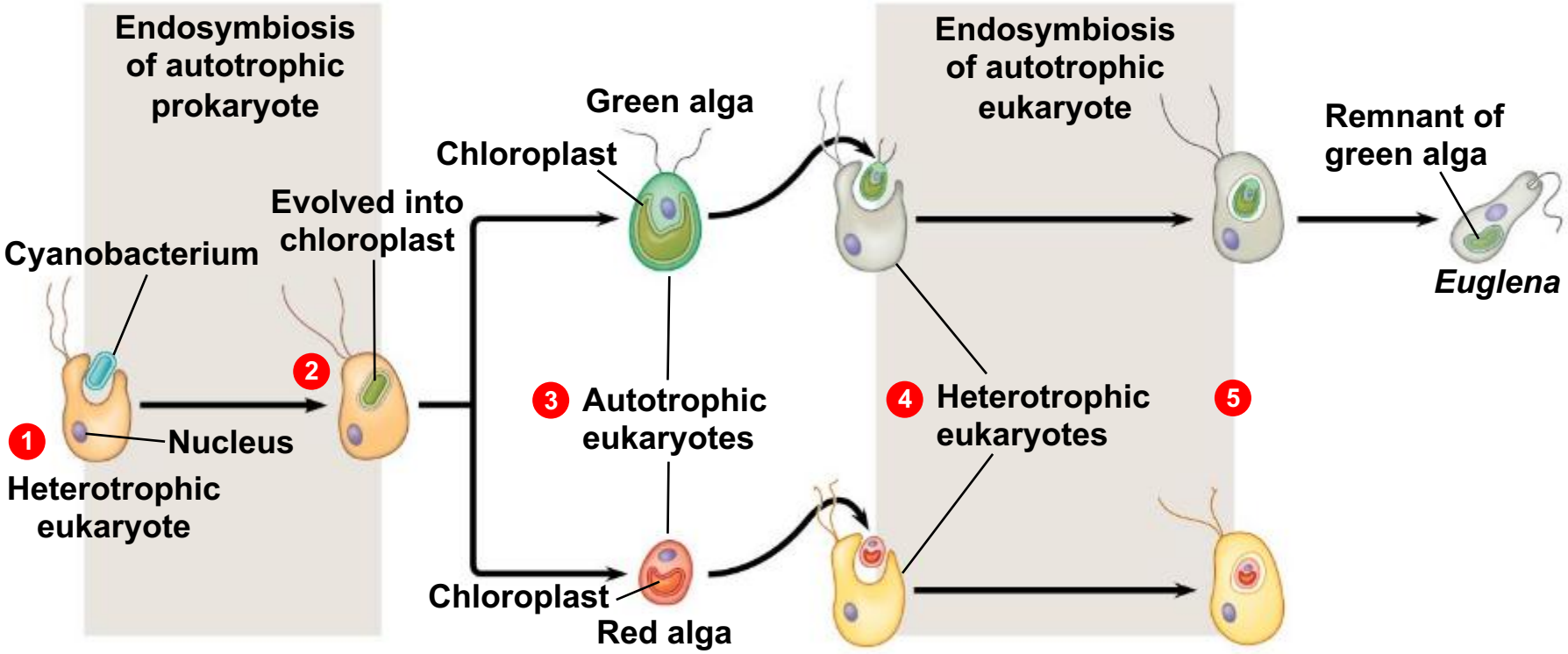
Figure 16.13-2



16.13 EVOLUTION CONNECTION: Endosymbiosis of unicellular algae is the key to much of protist diversity

- In **secondary endosymbiosis**, an autotrophic eukaryotic protist became endosymbiotic in a heterotrophic eukaryotic protist.
    4. Green algae and red algae became endosymbionts following ingestion by different heterotrophic eukaryotes. The heterotrophic host cells enclosed the algal cells in food vacuoles.
    5. But the algae—or parts of them—survived and became cellular organelles.

Figure 16.13-4



16.15 CONNECTION: Can algae provide a renewable source of energy?

- Lipid droplets in diatoms and other algae may serve as a renewable source of energy.
- If unicellular algae could be grown on a large scale, this oil could be harvested and processed into biodiesel.
- Numerous technical hurdles remain before industrial-scale production of biofuel from algae becomes a reality.

16.18 Archaeplastids include red algae, green algae, and land plants

- *Ulva*, or sea lettuce (石蓴), is a multicellular green alga with a complex life cycle that includes an **alternation of generations** that consists of a multicellular diploid (2*n*) form, the **sporophyte**, that alternates with a multicellular haploid (1*n*) form, the **gametophyte**.

Figure 16.18c-0-3

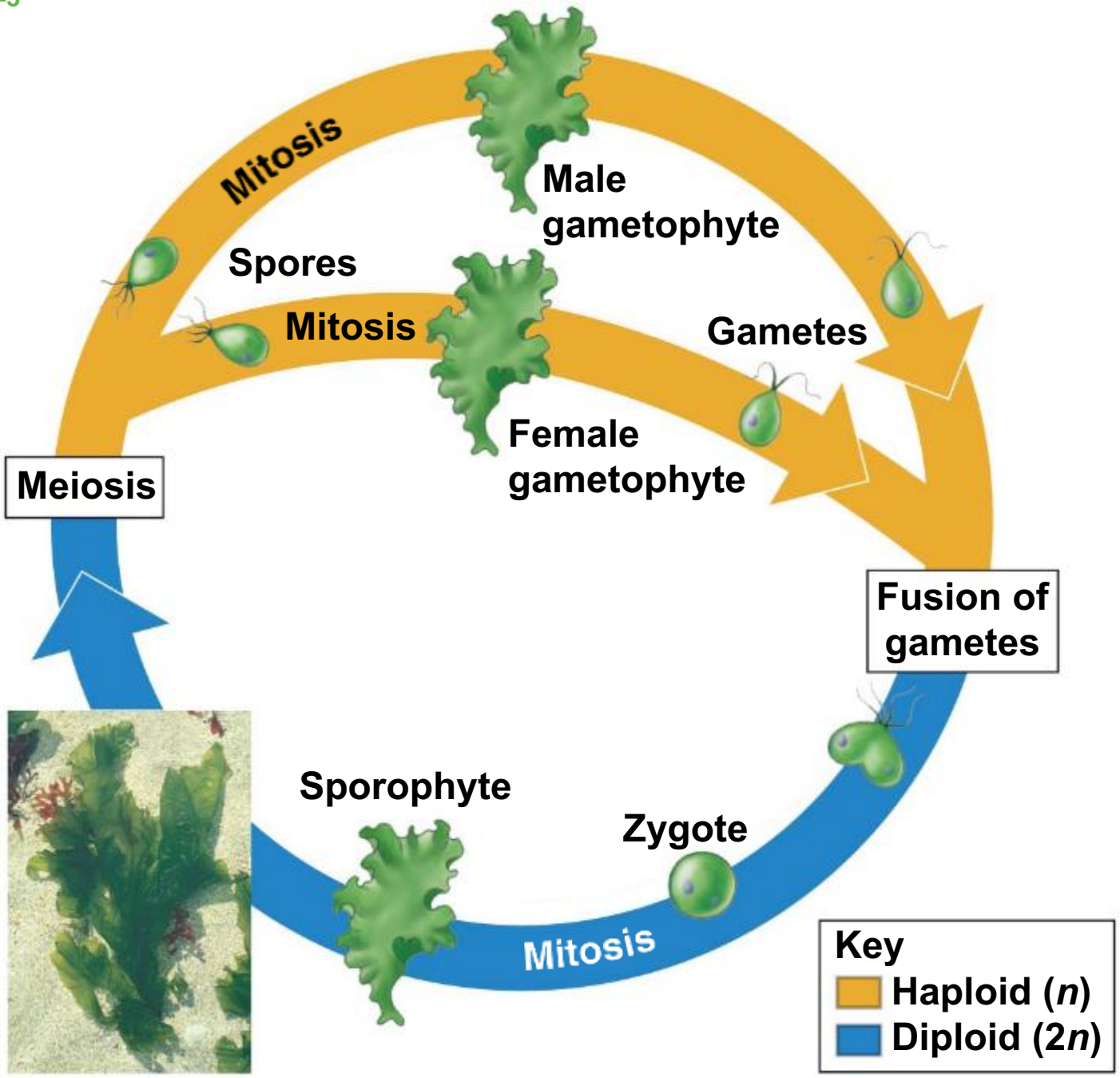


Figure 16.19b-0