海底的生命之泉

科學家近來在海底發現一種新的熱泉生態系統，分析結果顯示，地球上的生命可能由一些前所未知的方式演化而來。

撰文／布萊德雷（Alexander S. Bradley）　翻譯／王心瑩

這裡是生命的搖籃嗎？

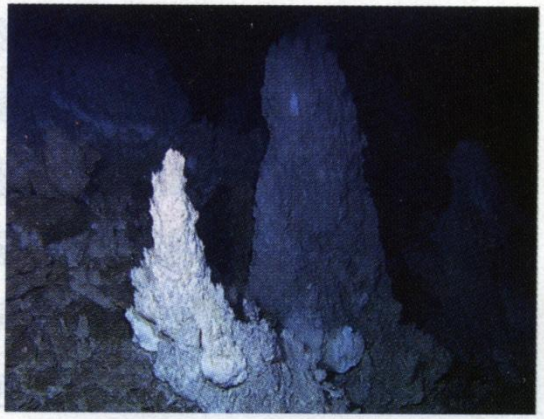
「失落的城市」熱泉坐落在水面下的山頂處，該處稱為亞特蘭提斯地塊，位於大西洋中洋脊板塊交界處以西15公里。經過研究，我們知道熱泉的煙囪構造如何形成，也發現那裡的化學反應非常特殊，地球上最初生命的誕生之地可能就類似這樣的地方。

這個地塊主要是由橄欖岩構成，滲入地塊裂縫的海水會與橄欖岩產生反應，將橄欖岩轉變為蛇紋岩。這種蛇紋石化作用會引發好幾個過程，都對「失落的城市」週遭的化學環境至關重要。首先，它使滲入岩石的熱水呈現鹼性，而且含有鈣；這些水從熱泉出口噴出、與海水混合後，會形成碳酸鈣，沉積在出口周圍，形成白色煙囪構造。其次，它使熱泉充滿了富含能量的氣體，因此生活在煙囪壁上和內部的甲烷菌之類微生物不需要太陽能便可繁衍。最後，蛇紋石化作用所產生的化學條件可以讓無機化合物合成出有機化合物，而這正是演化出生命的必要條件。

失落的城市……

「失落的城市」和「黑煙囪」都是海底熱泉，此外兩者大不相同。以下是「失落的城市」的幾個特點：

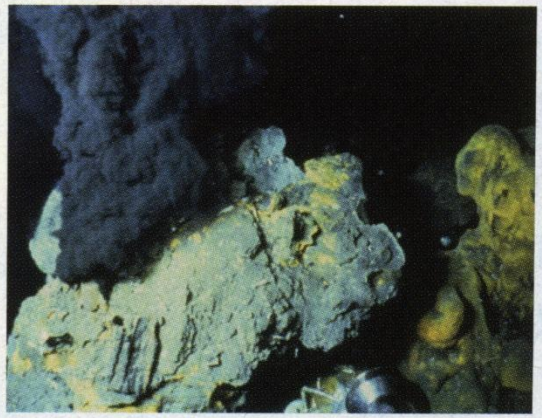
- 位於大西洋中洋脊火山群西方15公里處
- 水溫為90℃
- pH值偏鹼性
- 白煙囪是由碳酸鈣構成
- 該處有些生命形式可以獨立生存，不須仰賴太陽能



黑煙囪……

黑煙囪接近上升的岩漿，因此有許多特點與「失落的城市」完全不一樣：

- 位於大西洋中洋脊火山群中
- 水溫高達400℃
- pH值偏酸性
- 硫化物製造出黑煙，並累積構成煙囪
- 該處的生命形式必須間接仰賴太陽能



有些生物熱愛溫泉

根據現存生物遺傳物質的分析結果，「生命可能起源於熱泉生態系統」的假說或可成立，而當時的熱泉也許很類似「失落的城市」。科學家根據RNA序列畫出系譜樹，呈現出地球上所有生命的親緣關係。如同「失落的城市」的甲烷菌（屬於甲烷團聚形太古生物目），位於系譜樹根部的許多微生物住在高溫的熱泉環境，有些位於陸地上，有些在海底，而且那些微生物（橘色）都可利用氫，顯示地球上所有生物最早的共同祖先便住在此種環境。

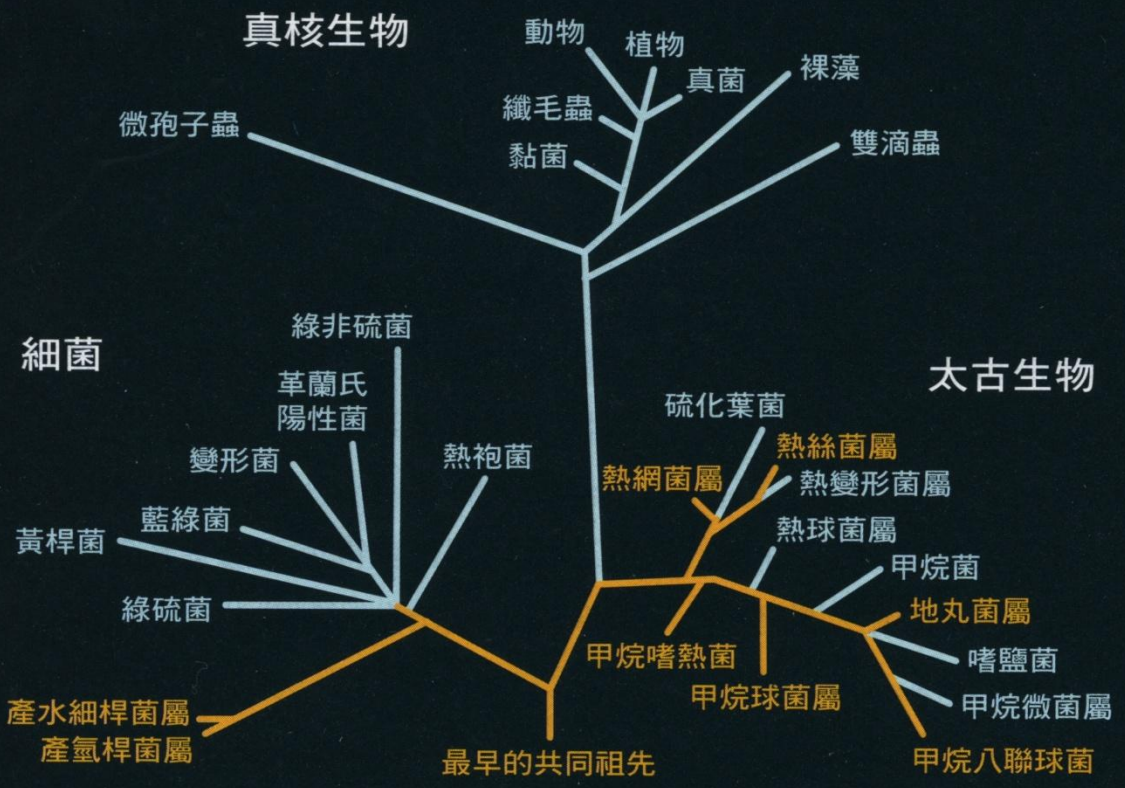
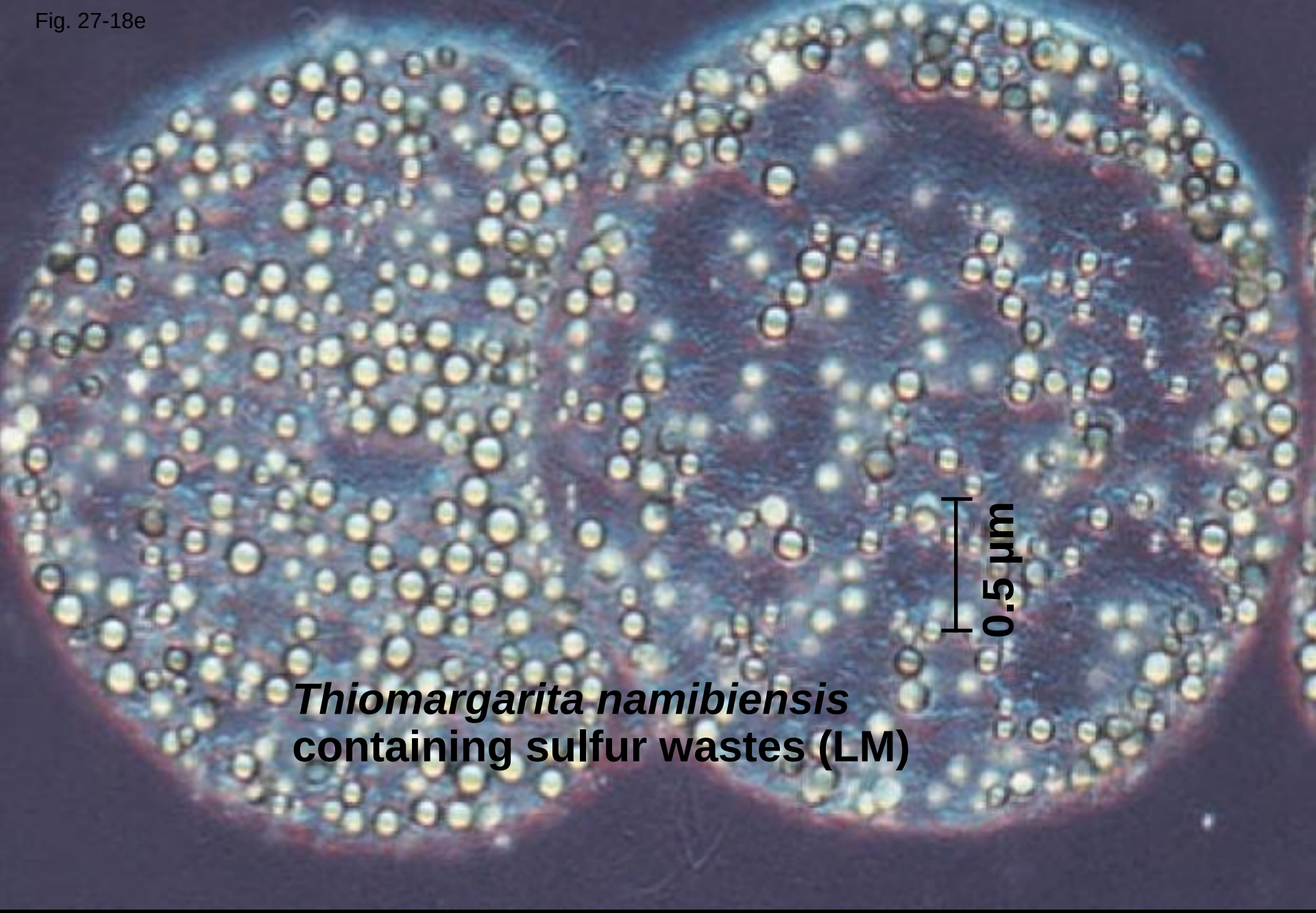
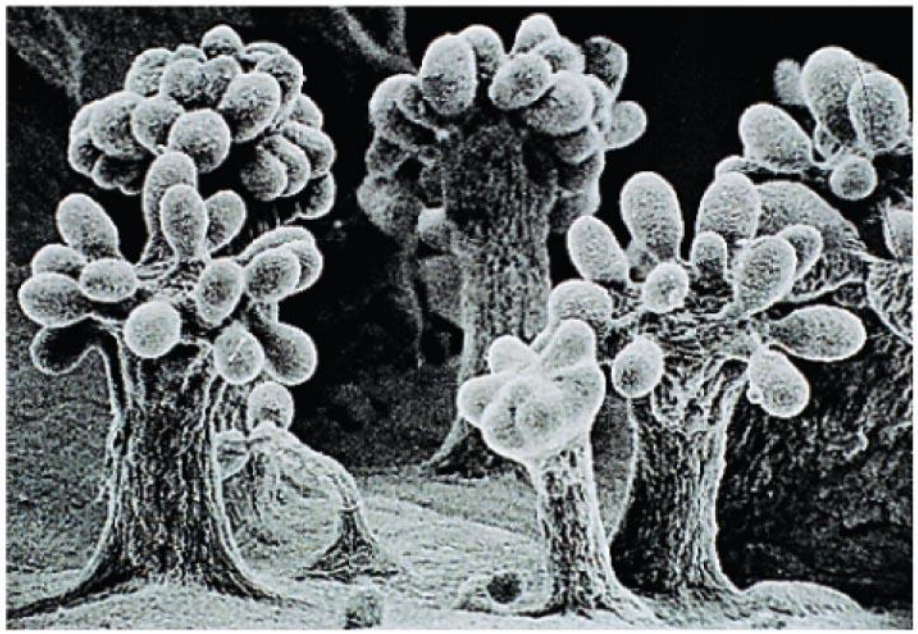


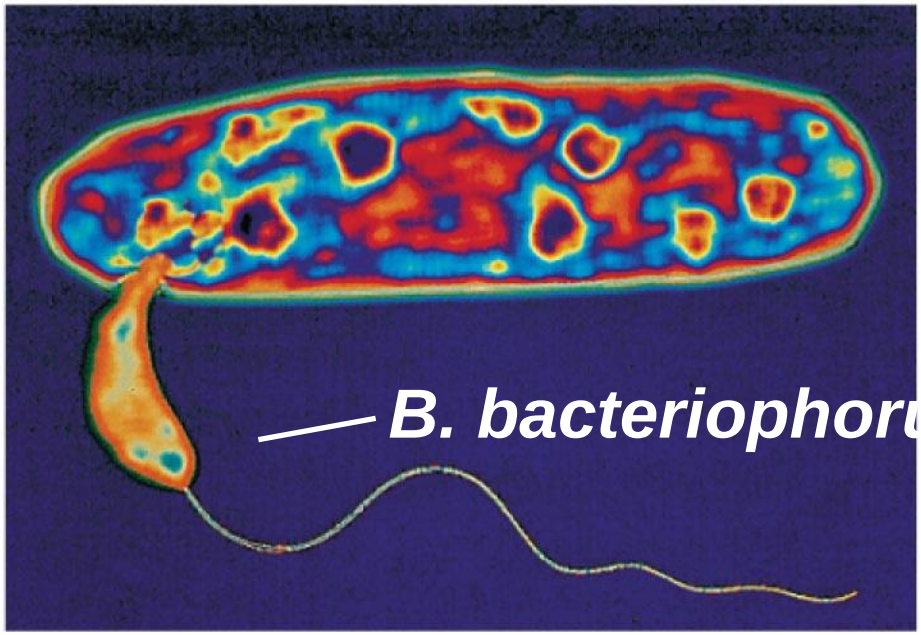
Fig. 27-18e



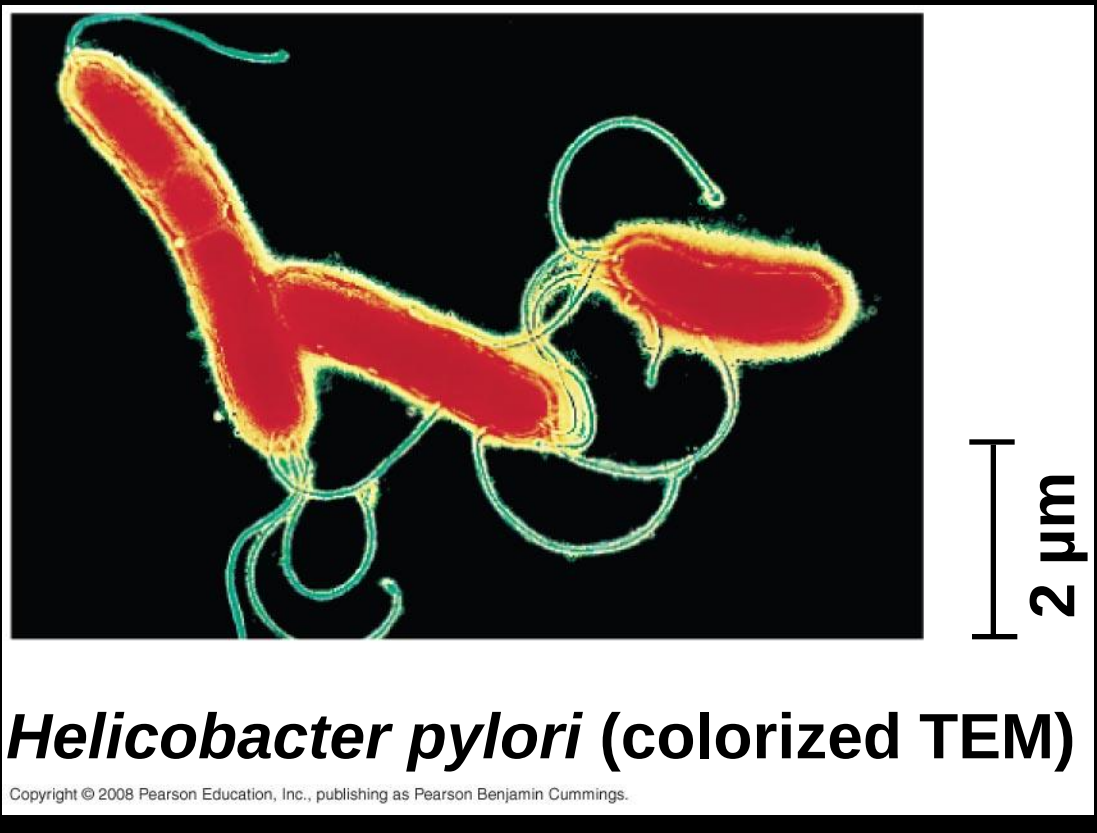
Thiomargarita namibiensis **containing sulfur wastes (LM)**



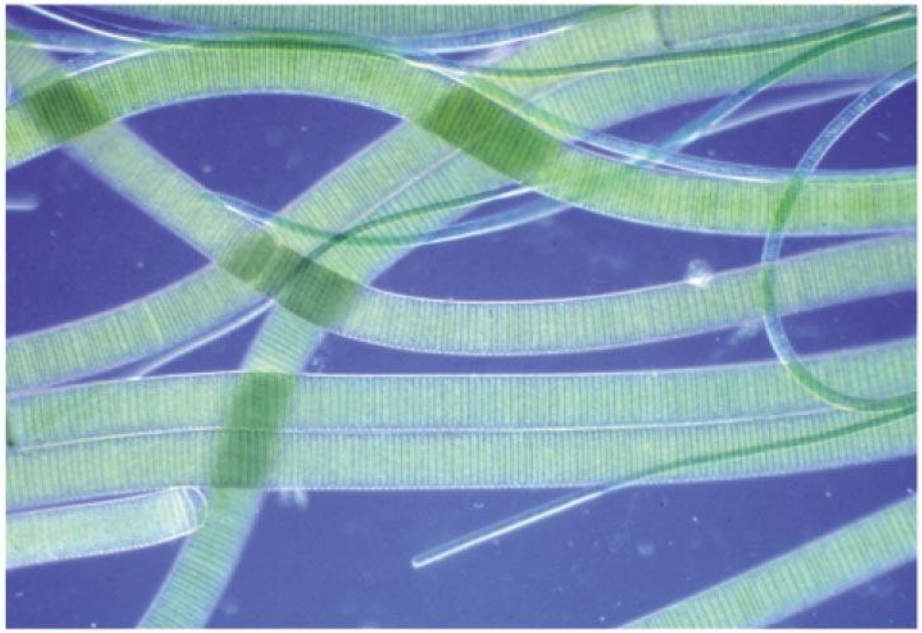
Fruiting bodies of *Chondromyces crocatus*, a myxobacterium (SEM)



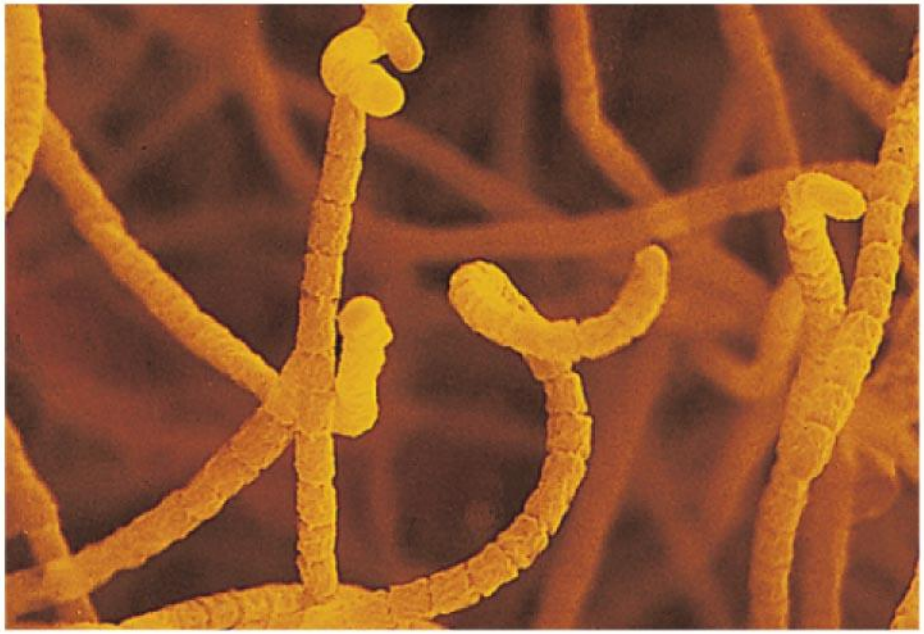
Bdellovibrio bacteriophorus **attacking a larger bacterium (colorized TEM)**



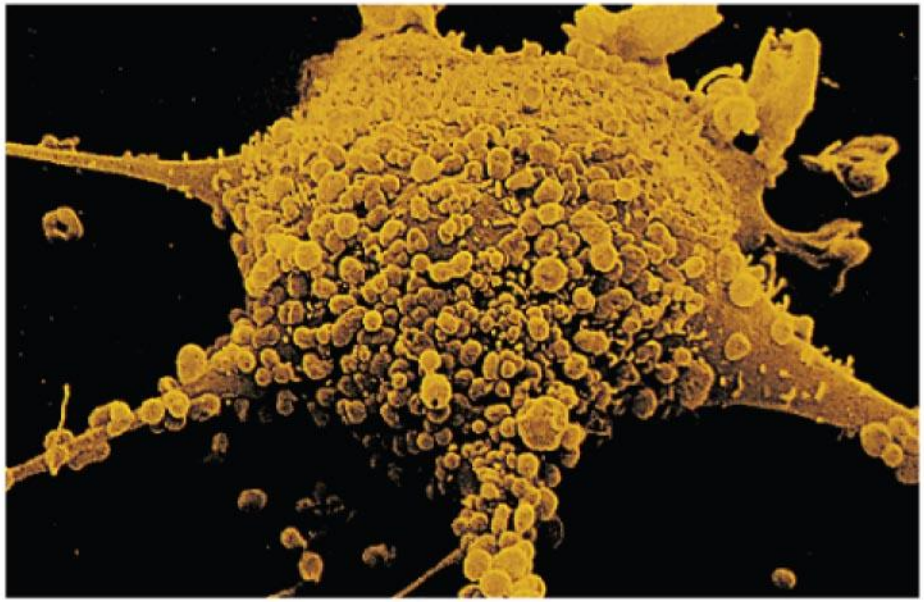
Helicobacter pylori **(colorized TEM)**



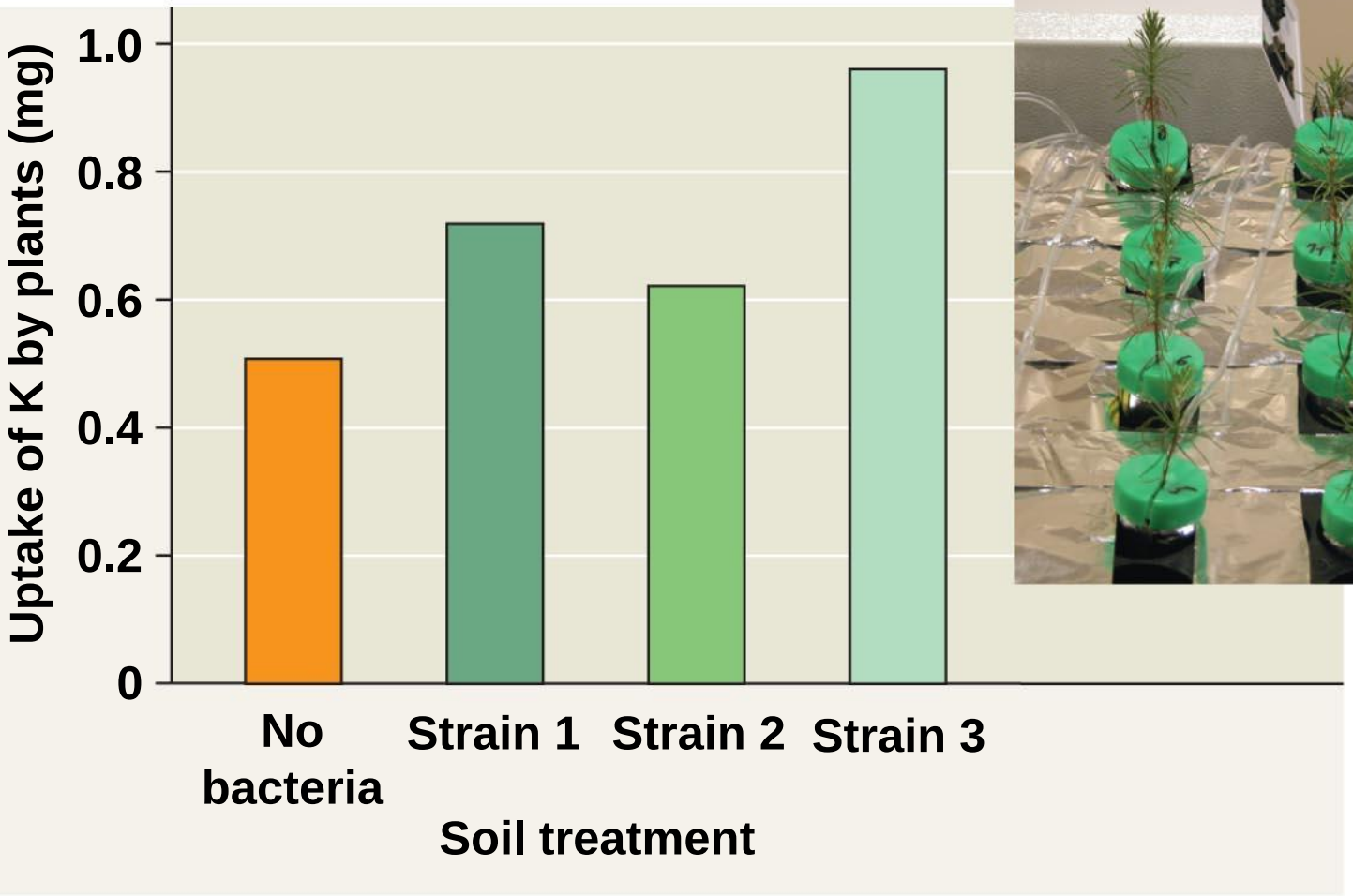
Two species of *Oscillatoria*, filamentous cyanobacteria (LM)

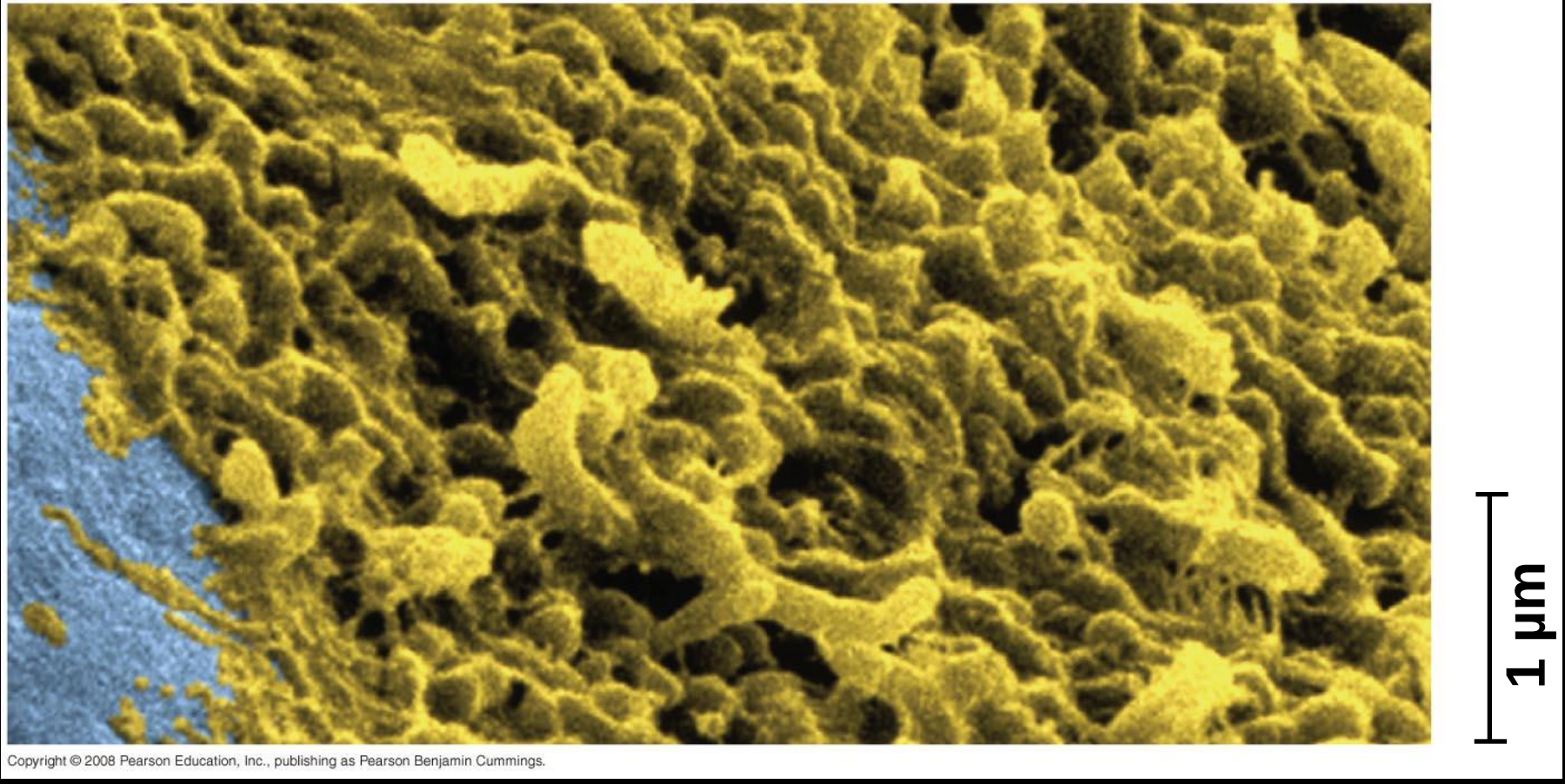


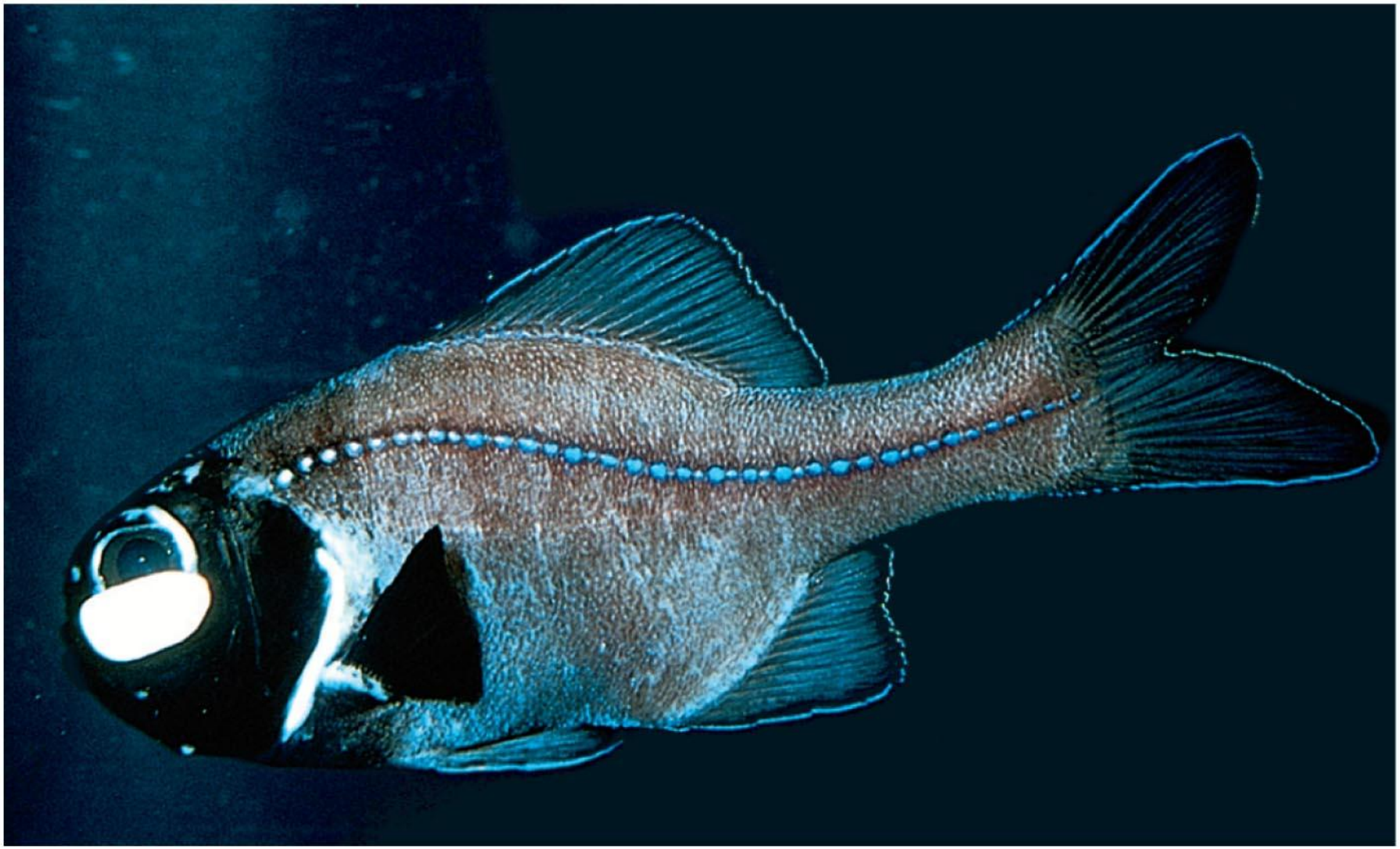
***Streptomyces*, the source of many antibiotics (colorized SEM)**

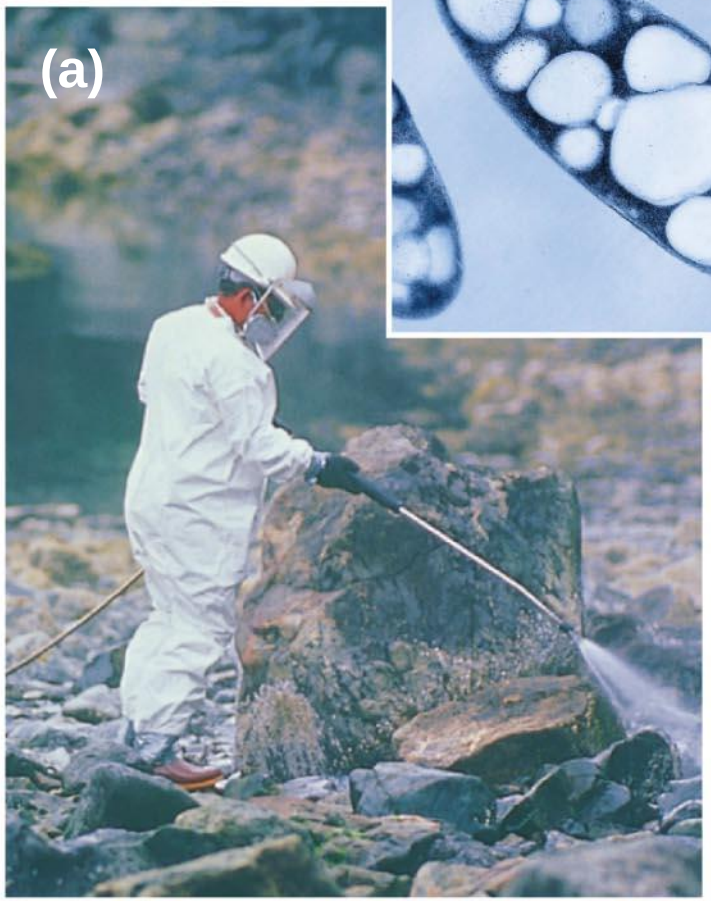


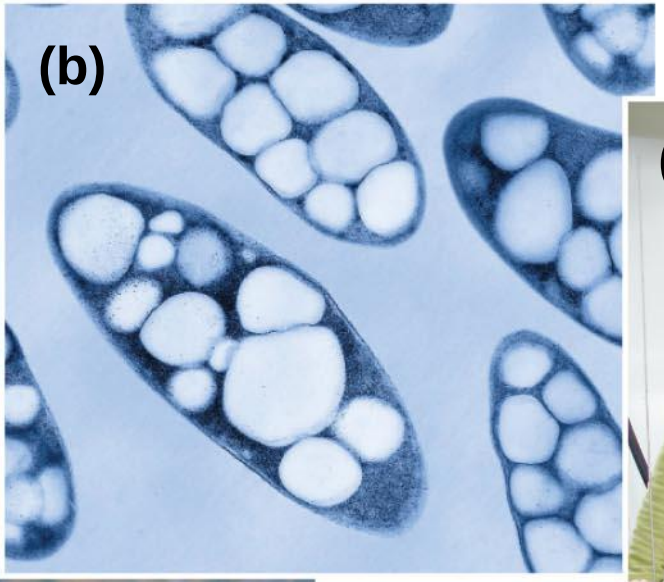
Hundreds of mycoplasmas covering a human fibroblast cell (colorized SEM)

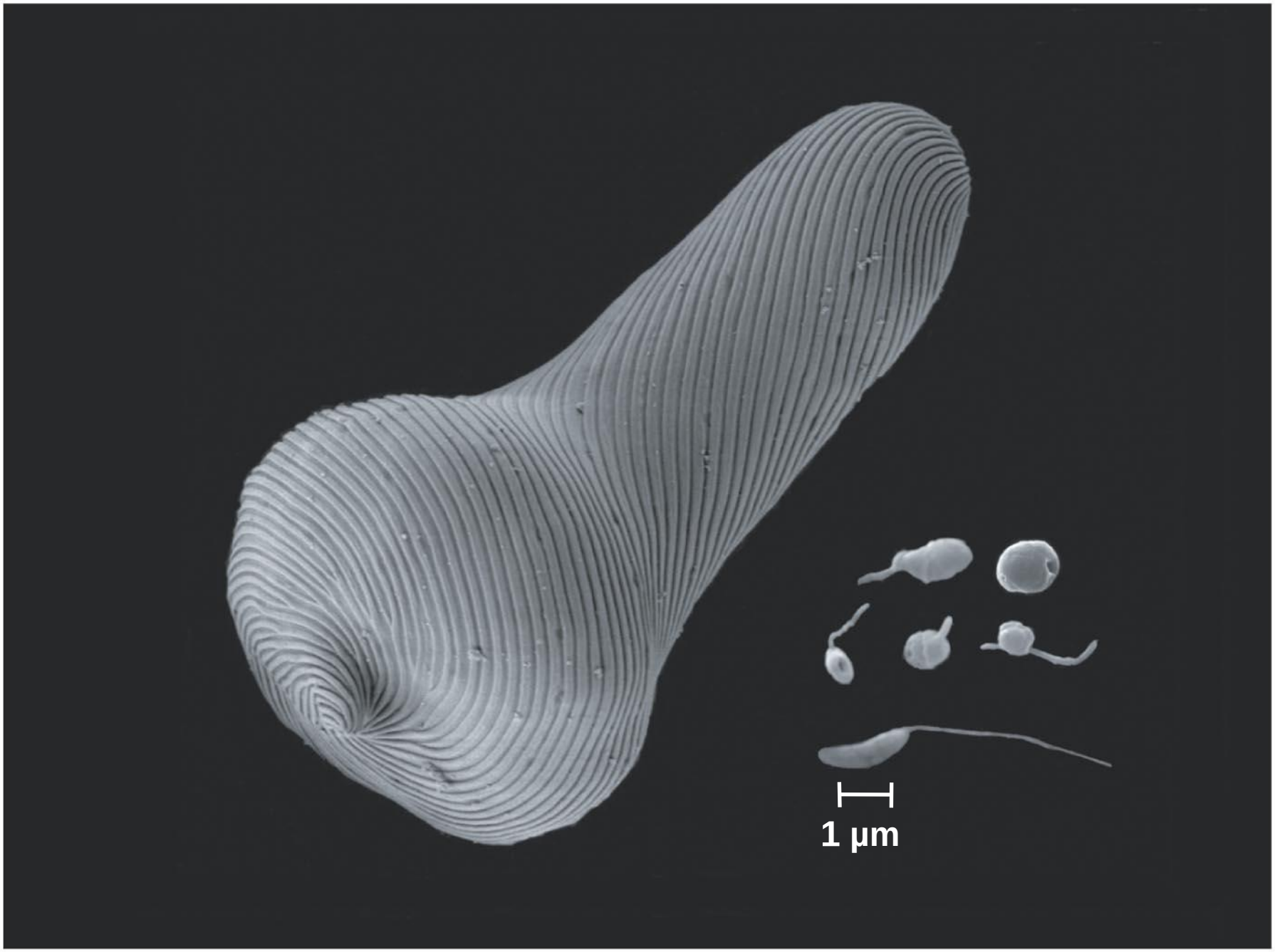


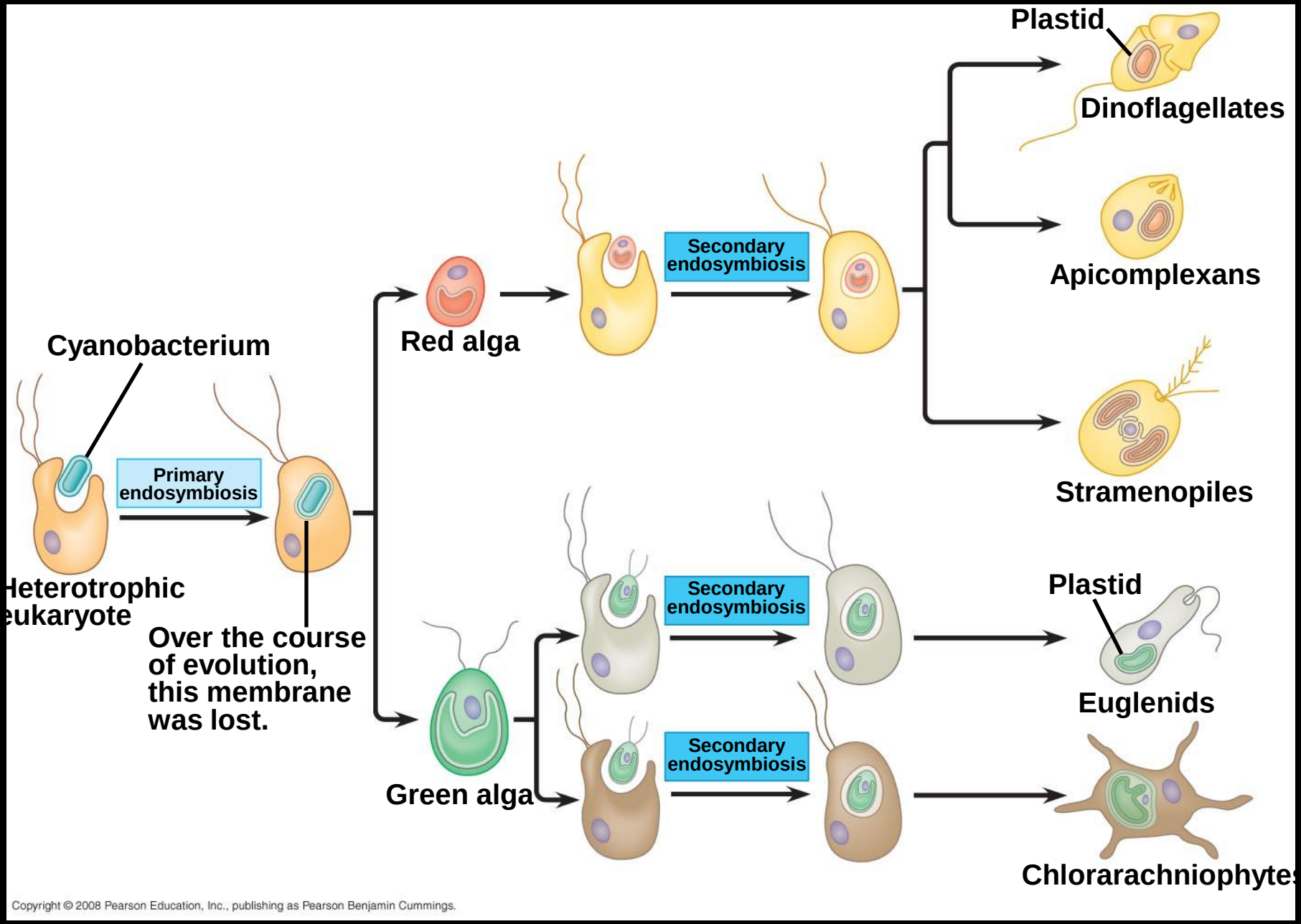


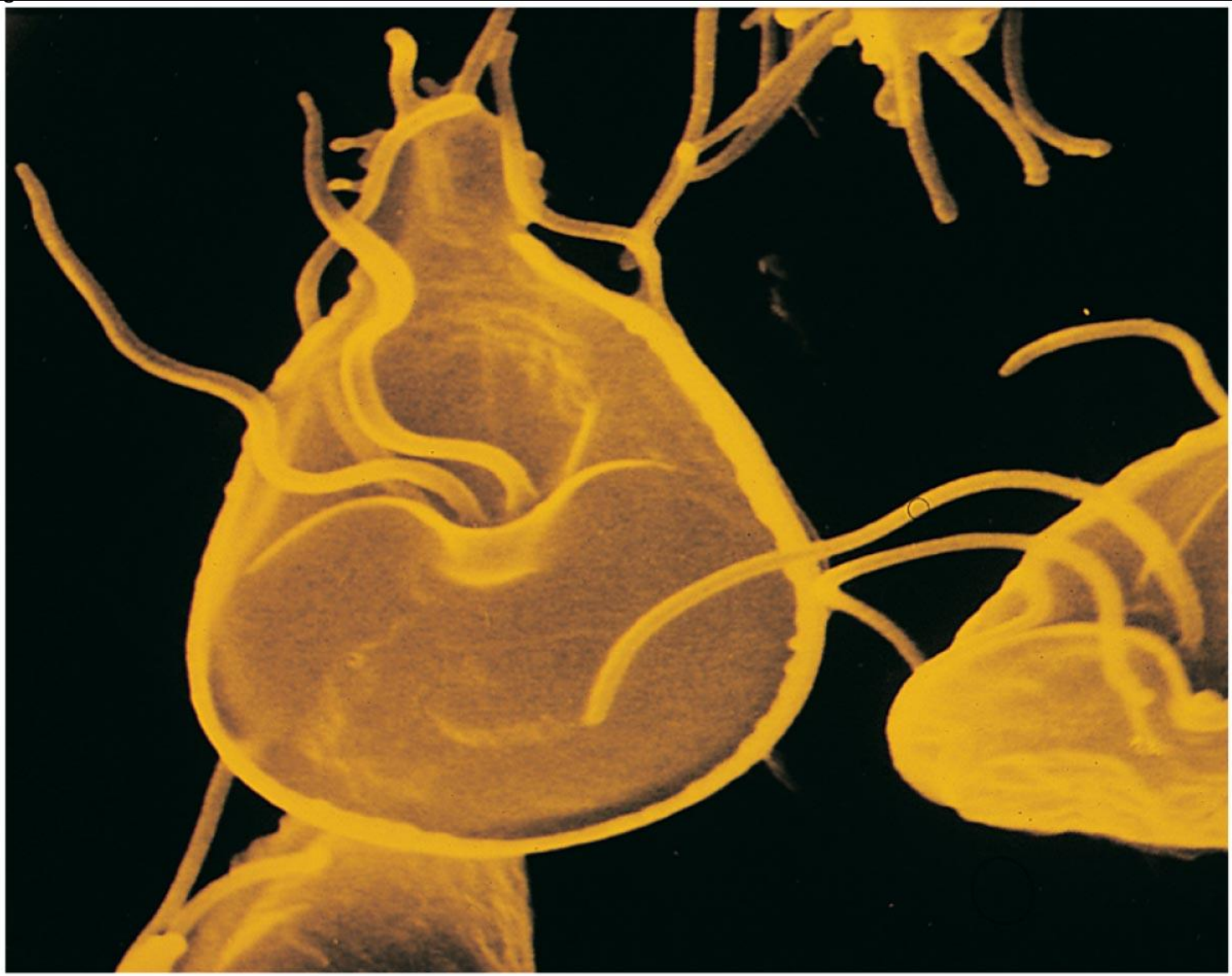






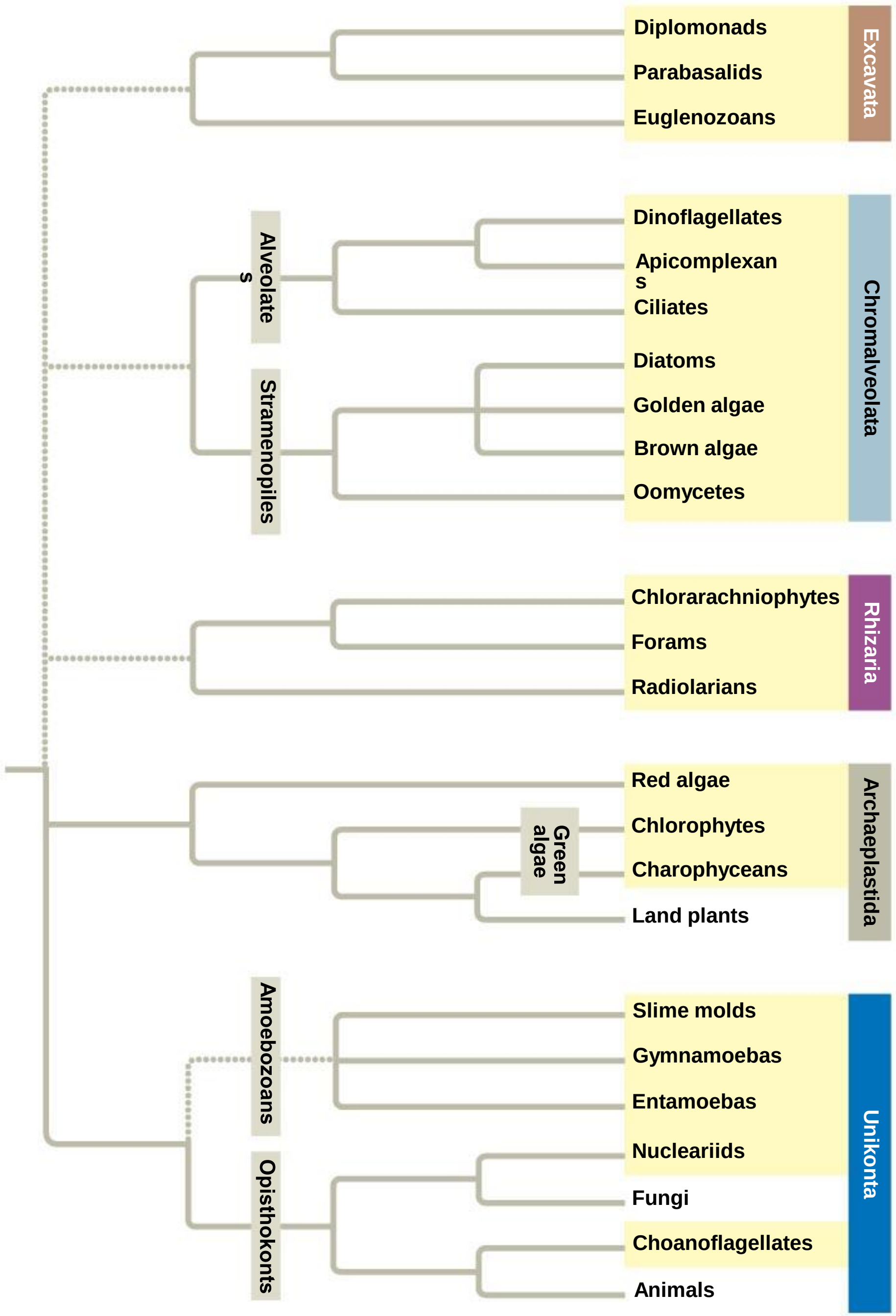


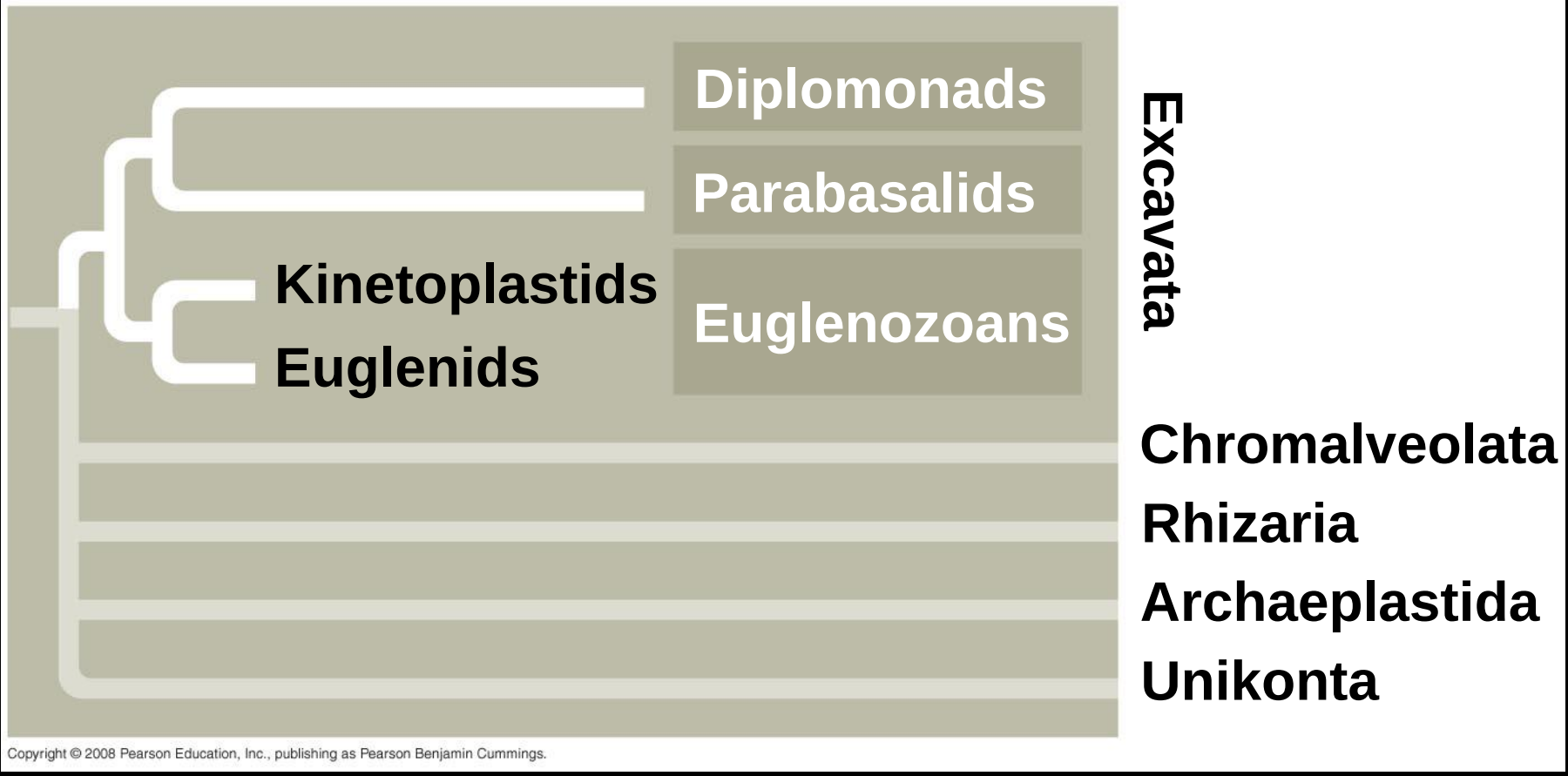




Five Supergroups of Eukaryotes

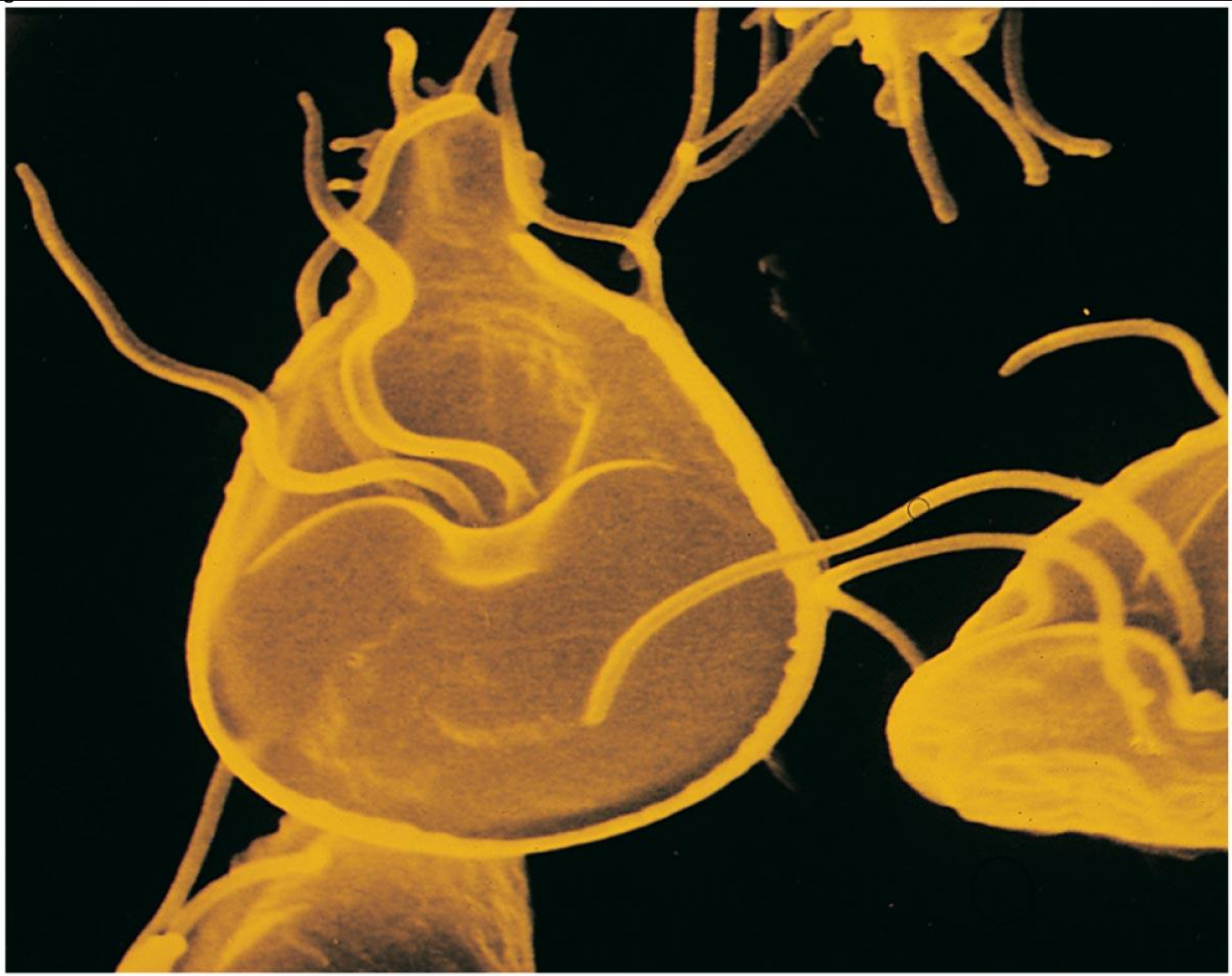
- It is no longer thought that amitochondriates (lacking mitochondria) are the oldest lineage of eukaryotes
- Our understanding of the relationships among protist groups continues to change rapidly
- One hypothesis divides all eukaryotes (including protists) into five supergroups



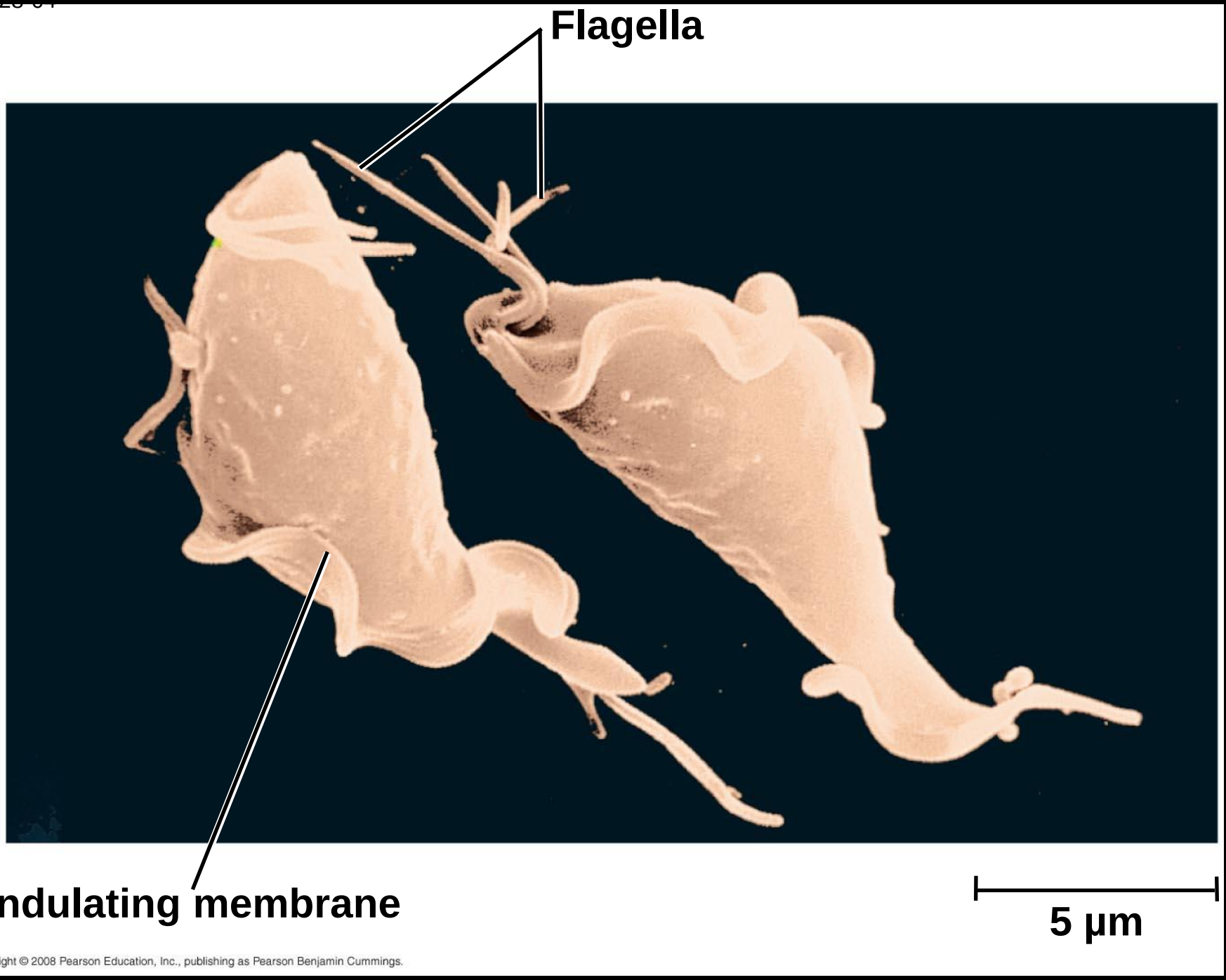


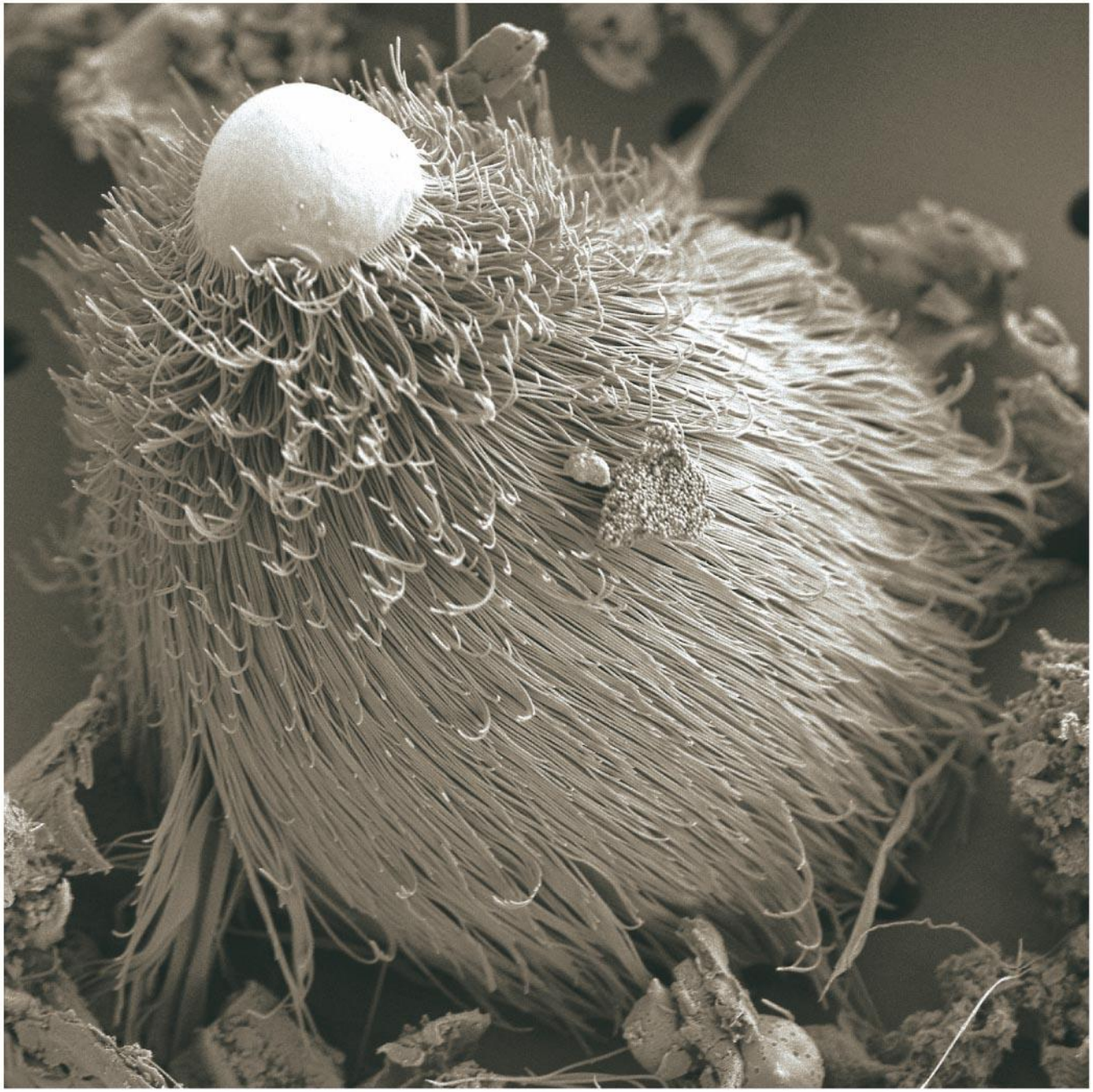
Diplomonads and Parabasalids

- These 2 groups live in anaerobic environments, lack plastids, and have modified mitochondria
- **Diplomonads**
  - Have modified mitochondria called *mitosomes*
  - Derive energy anaerobically, for example, by glycolysis
  - Have two equal-sized nuclei and multiple flagella
  - Are often parasites, for example, *Giardia intestinalis*



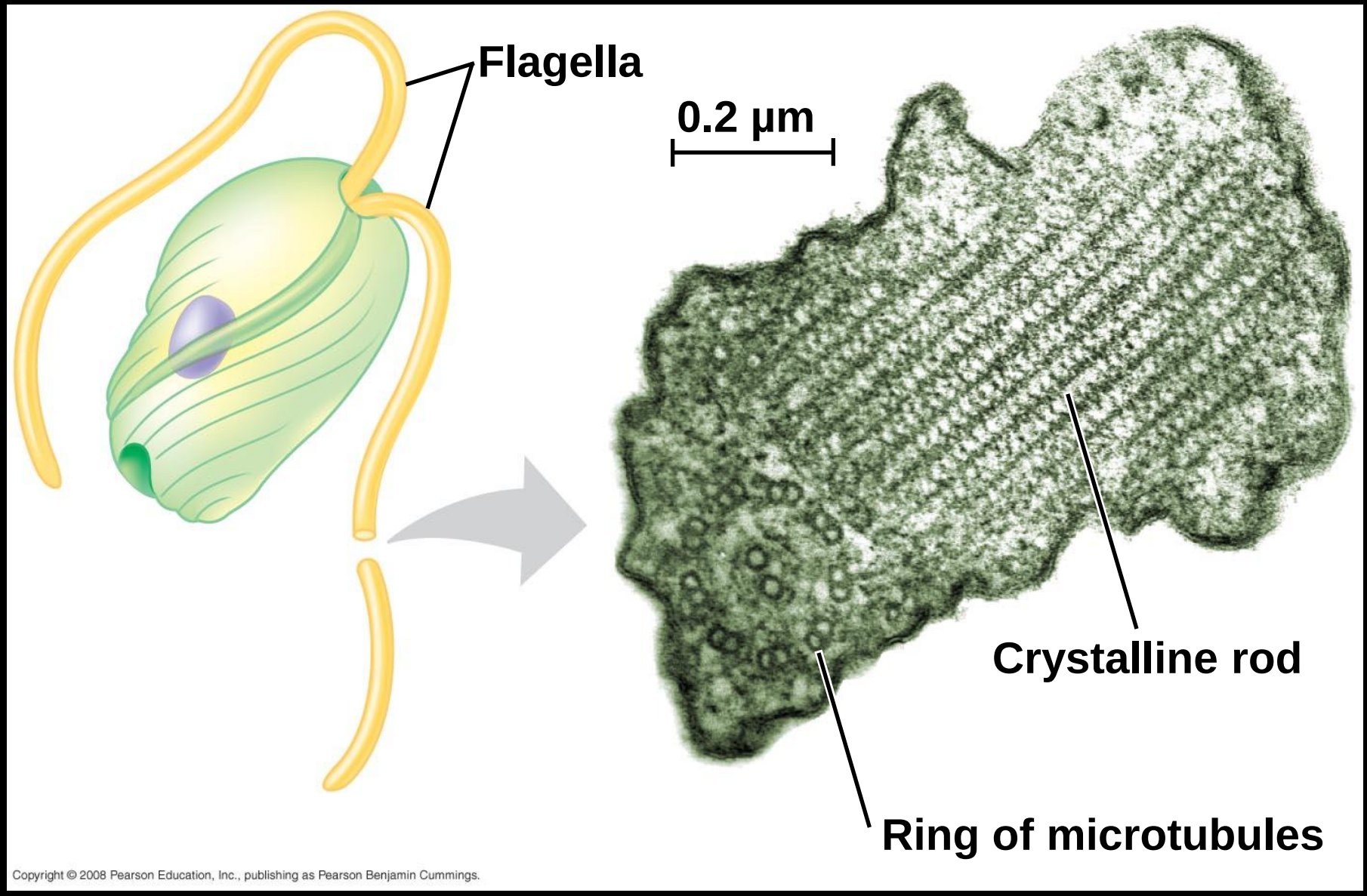
- **Parabasalids**
  - Have reduced mitochondria called *hydrogenosomes* that generate some energy anaerobically
  - Include *Trichomonas vaginalis*, the pathogen that causes yeast infections in human females





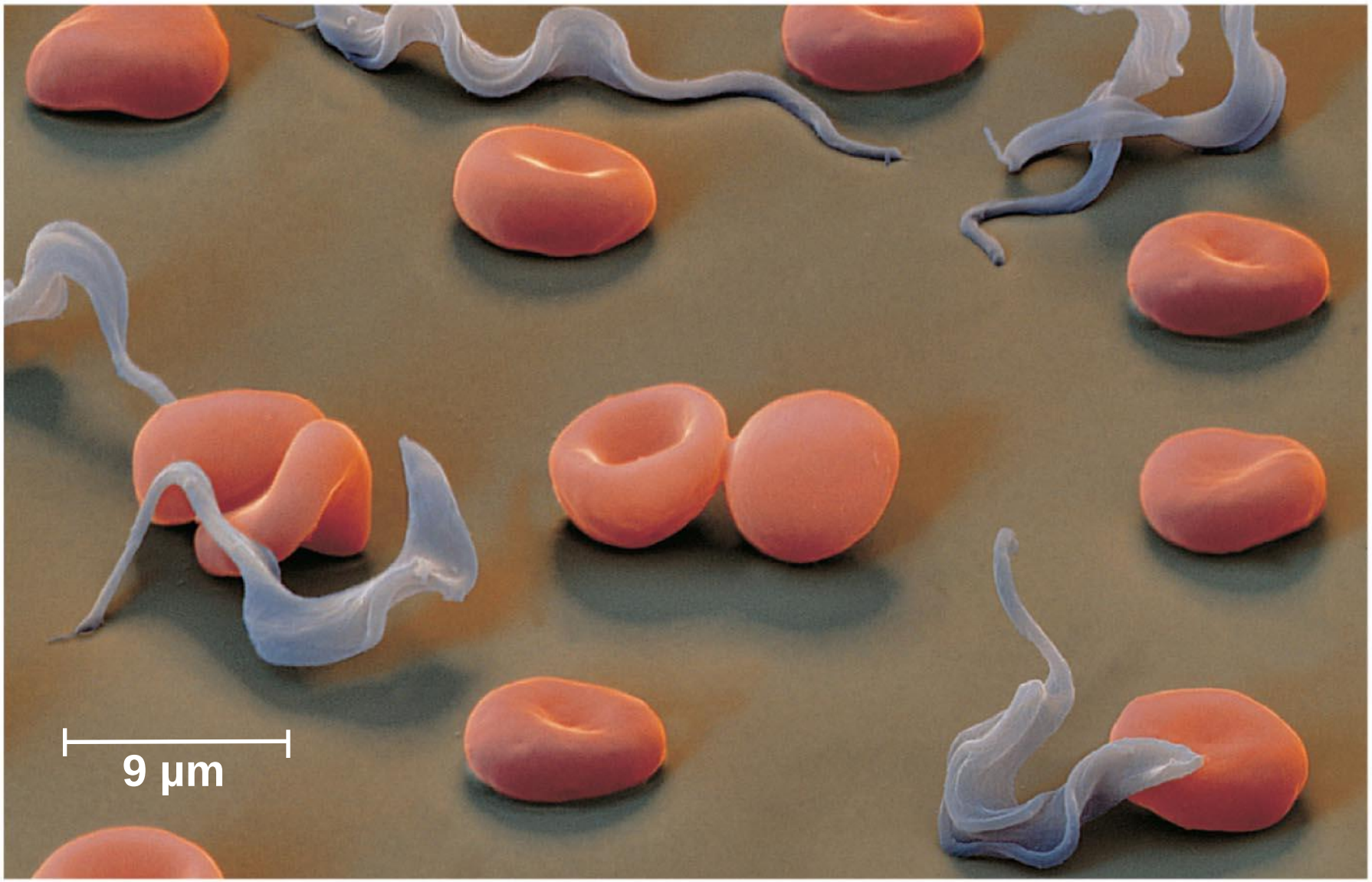
Euglenozoans

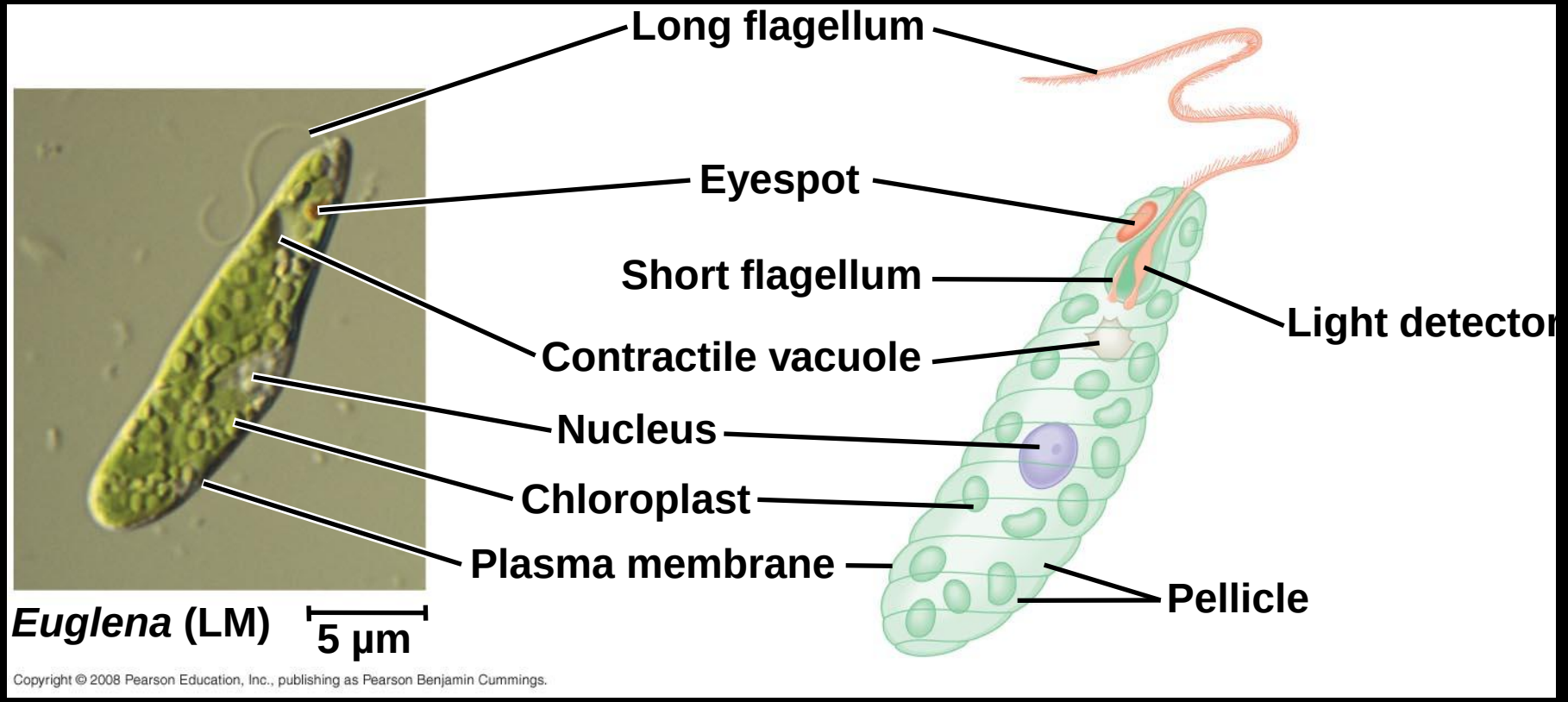
- **Euglenozoa** is a diverse clade that includes predatory heterotrophs, photosynthetic autotrophs, and pathogenic parasites
- The main feature distinguishing them as a clade is a spiral or crystalline rod of unknown function inside their flagella
- This clade includes the kinetoplastids and euglenids

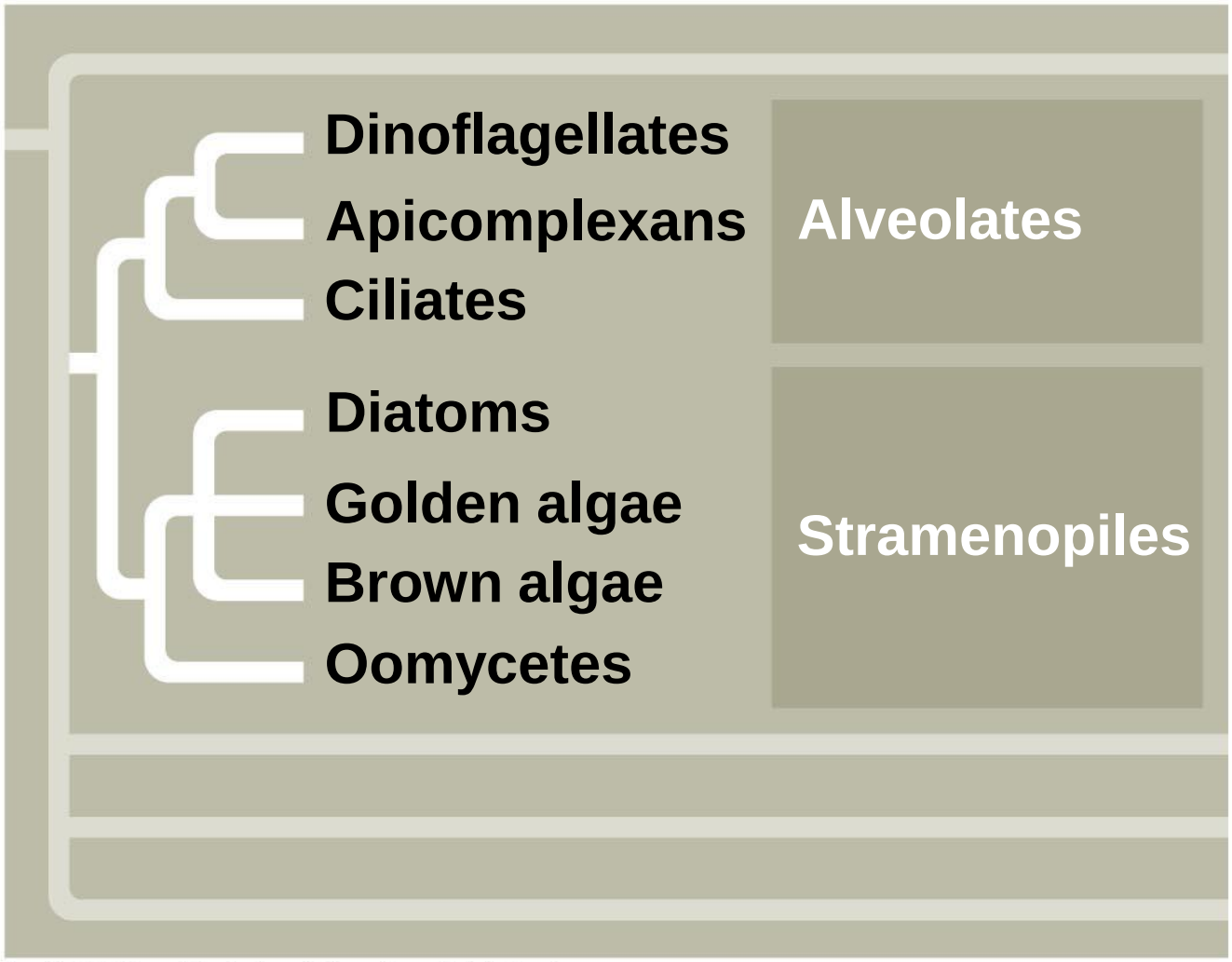


Kinetoplastids

- **Kinetoplastids** have a single mitochondrion with an organized mass of DNA called a *kinetoplast*
- They include free-living consumers of prokaryotes in freshwater, marine, and moist terrestrial ecosystems
- This group includes *Trypanosoma*, which causes sleeping sickness in humans
- Another pathogenic trypanosome causes Chagas' disease







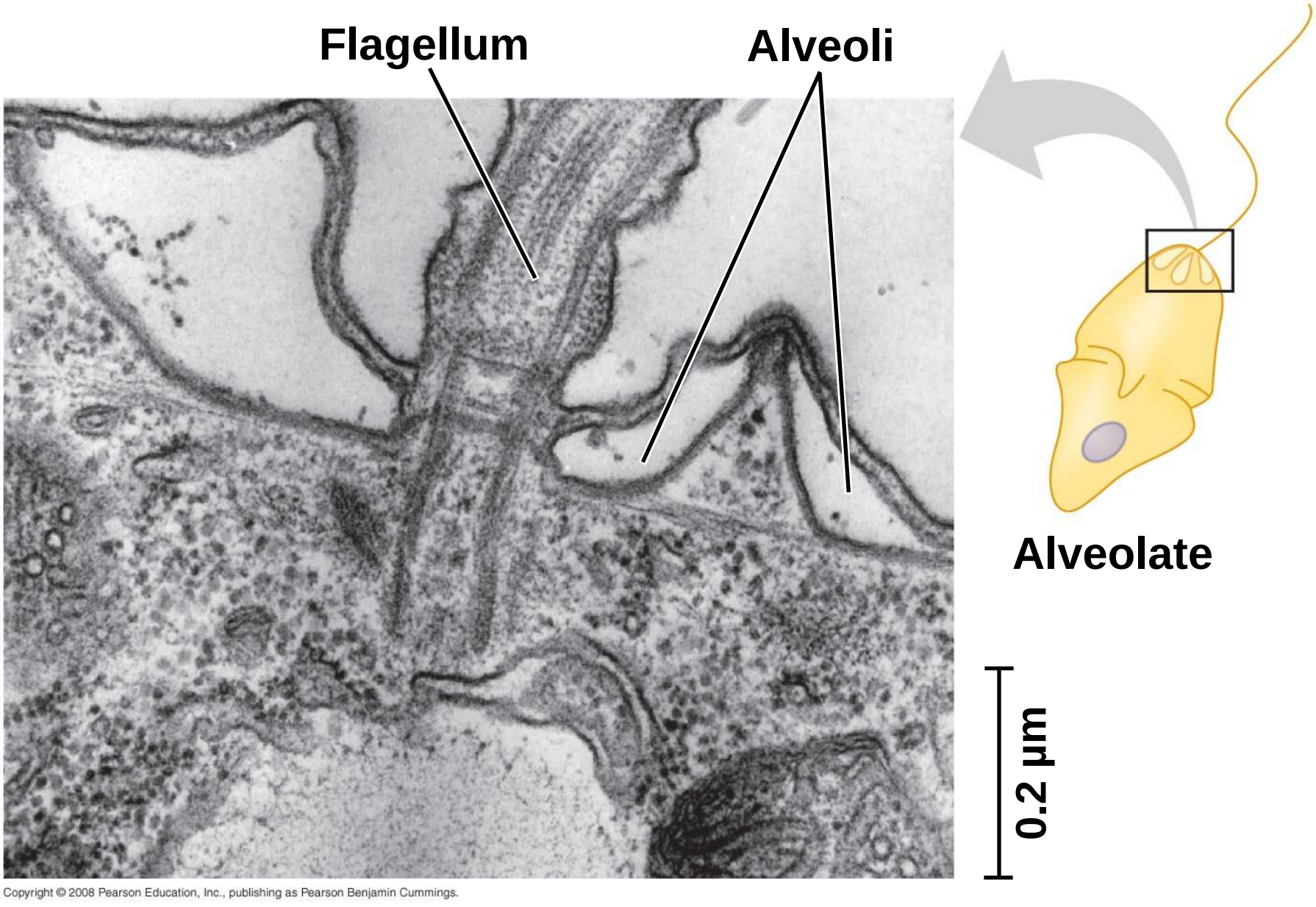
Excavata

Chromalveolata

Rhizaria

Archaeplastida

Unikonta

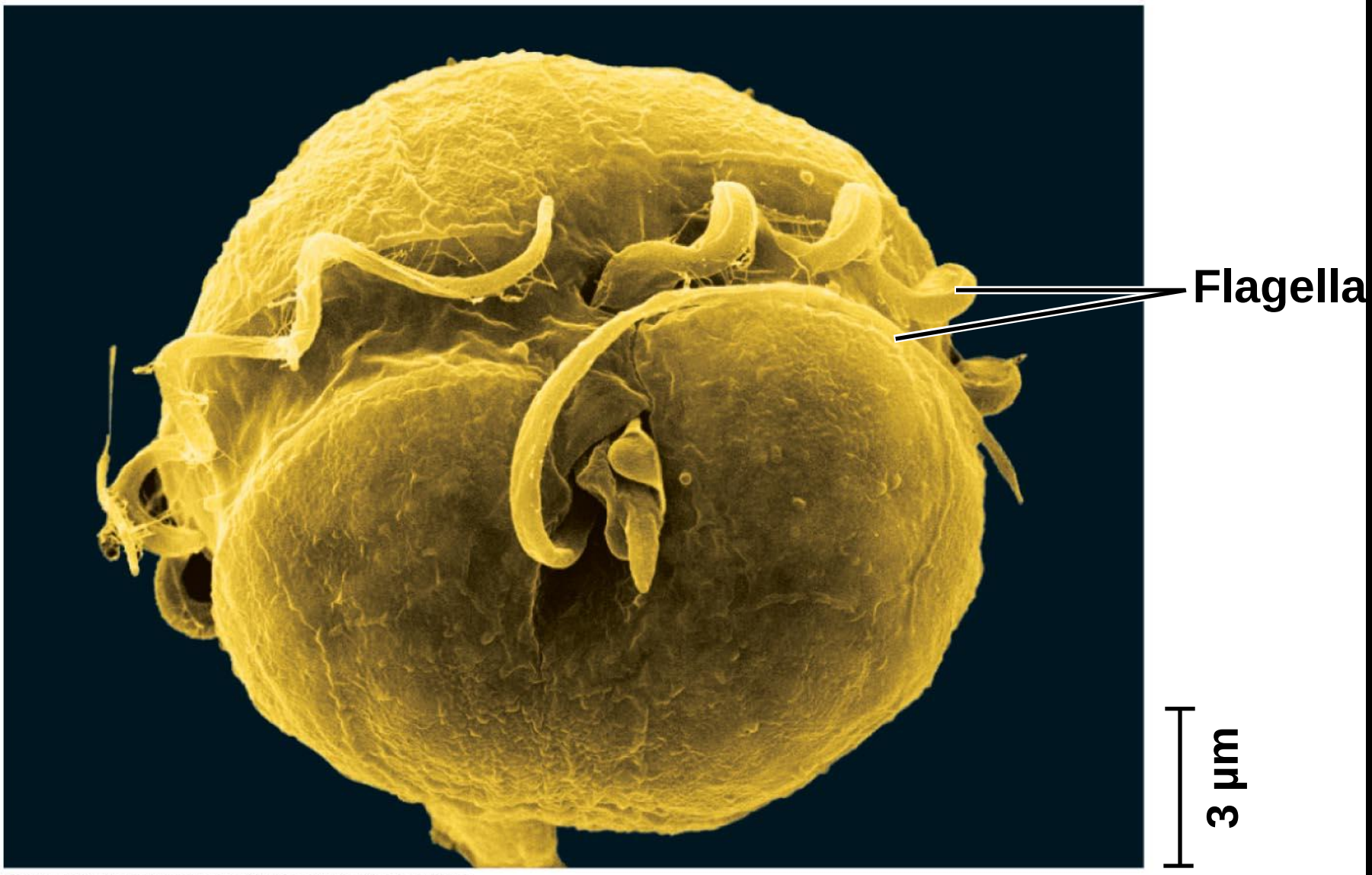


Dinoflagellates

- **Dinoflagellates** are a diverse group of aquatic mixotrophs and heterotrophs
- They are abundant components of both marine and freshwater phytoplankton
- Each has a characteristic shape that in many species is reinforced by internal plates of cellulose

PLAY Video: Dinoflagellate

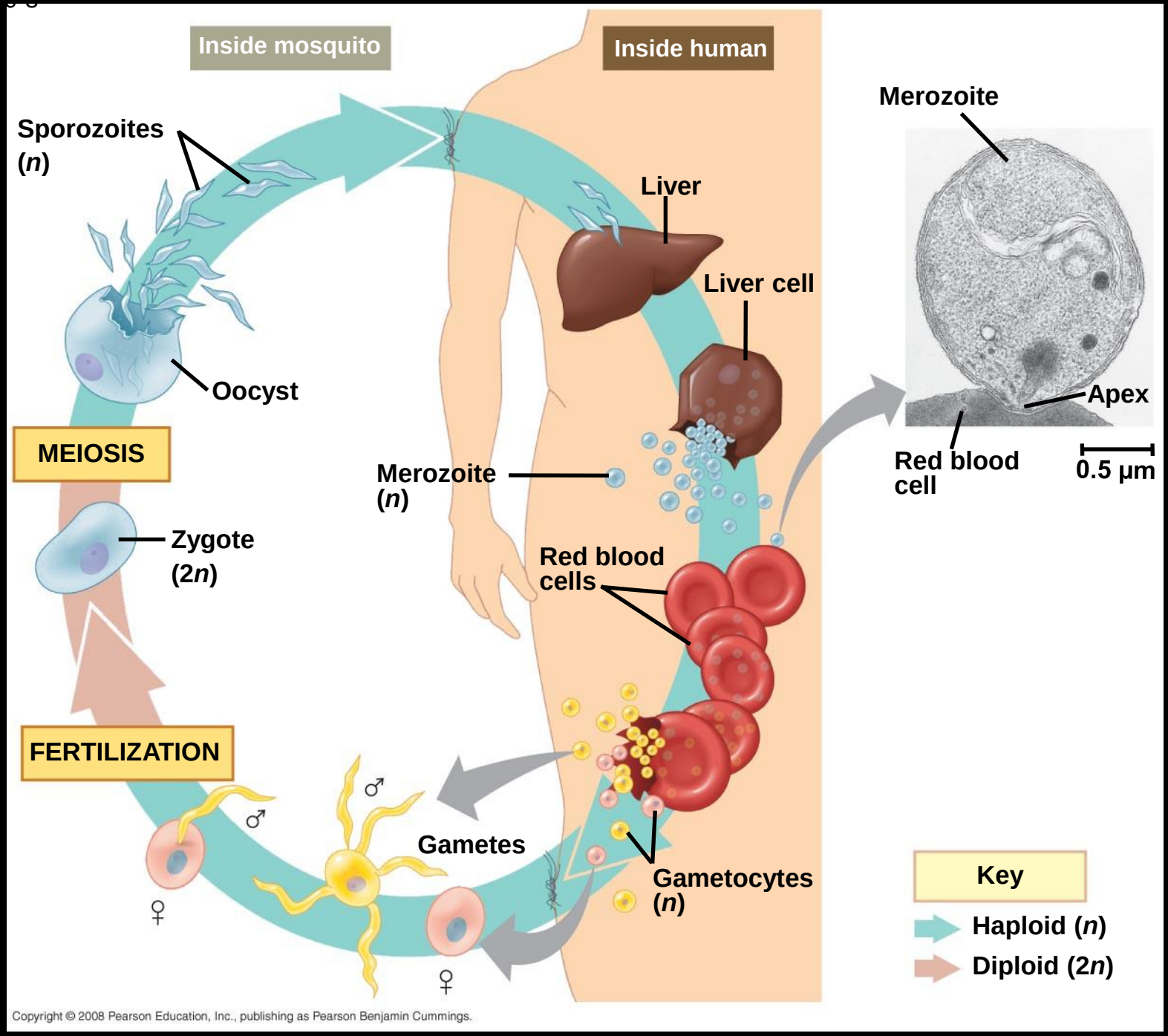
- Two flagella make them spin as they move through the water
- Dinoflagellate blooms are the cause of toxic “red tides”



Apicomplexans

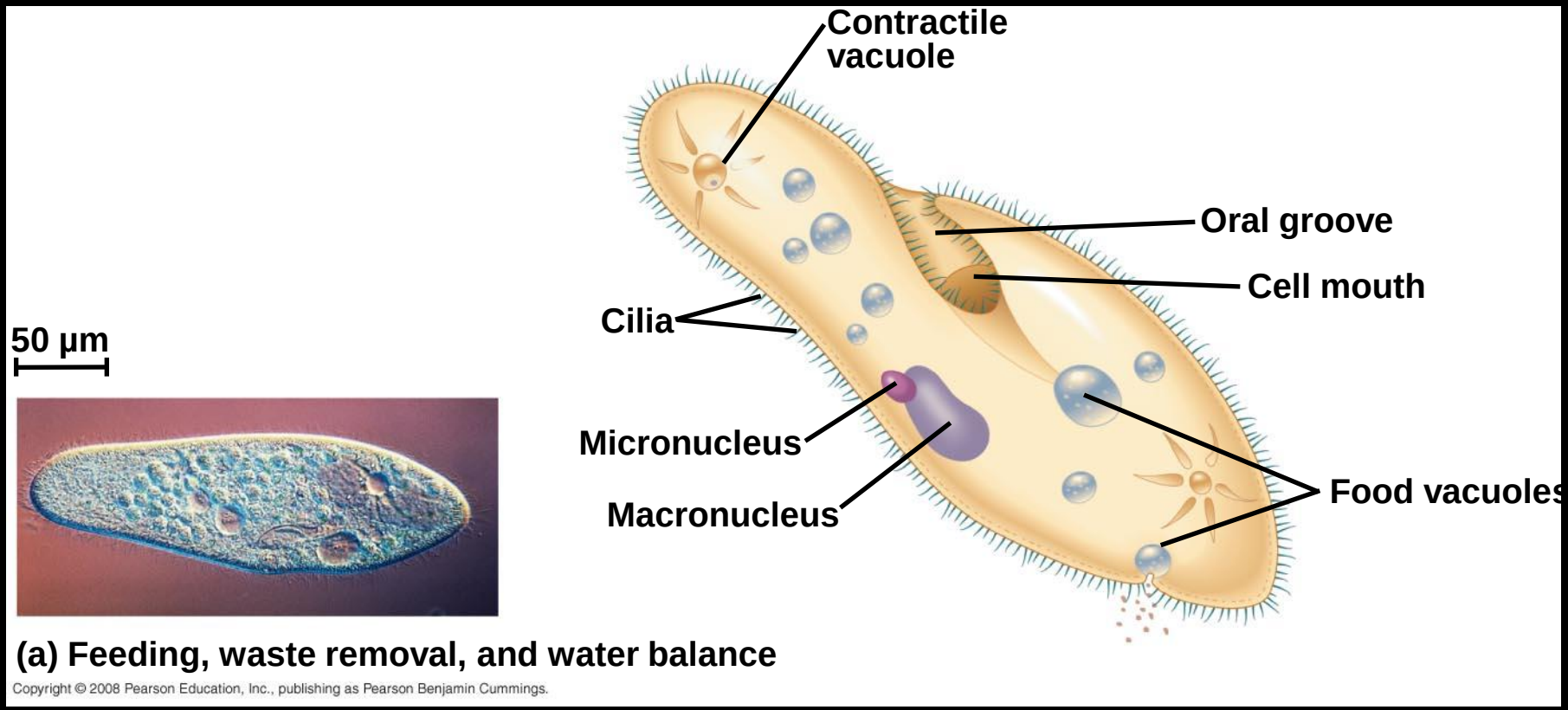
- **Apicomplexans** are parasites of animals, and some cause serious human diseases
- One end, the apex, contains a complex of organelles specialized for penetrating a host
- They have a nonphotosynthetic plastid, the apicoplast
- Most have sexual and asexual stages that require two or more different host species for completion

- The apicomplexan *Plasmodium* is the parasite that causes malaria
- *Plasmodium* requires both mosquitoes and humans to complete its life cycle
- Approximately 2 million people die each year from malaria
- Efforts are ongoing to develop vaccines that target this pathogen

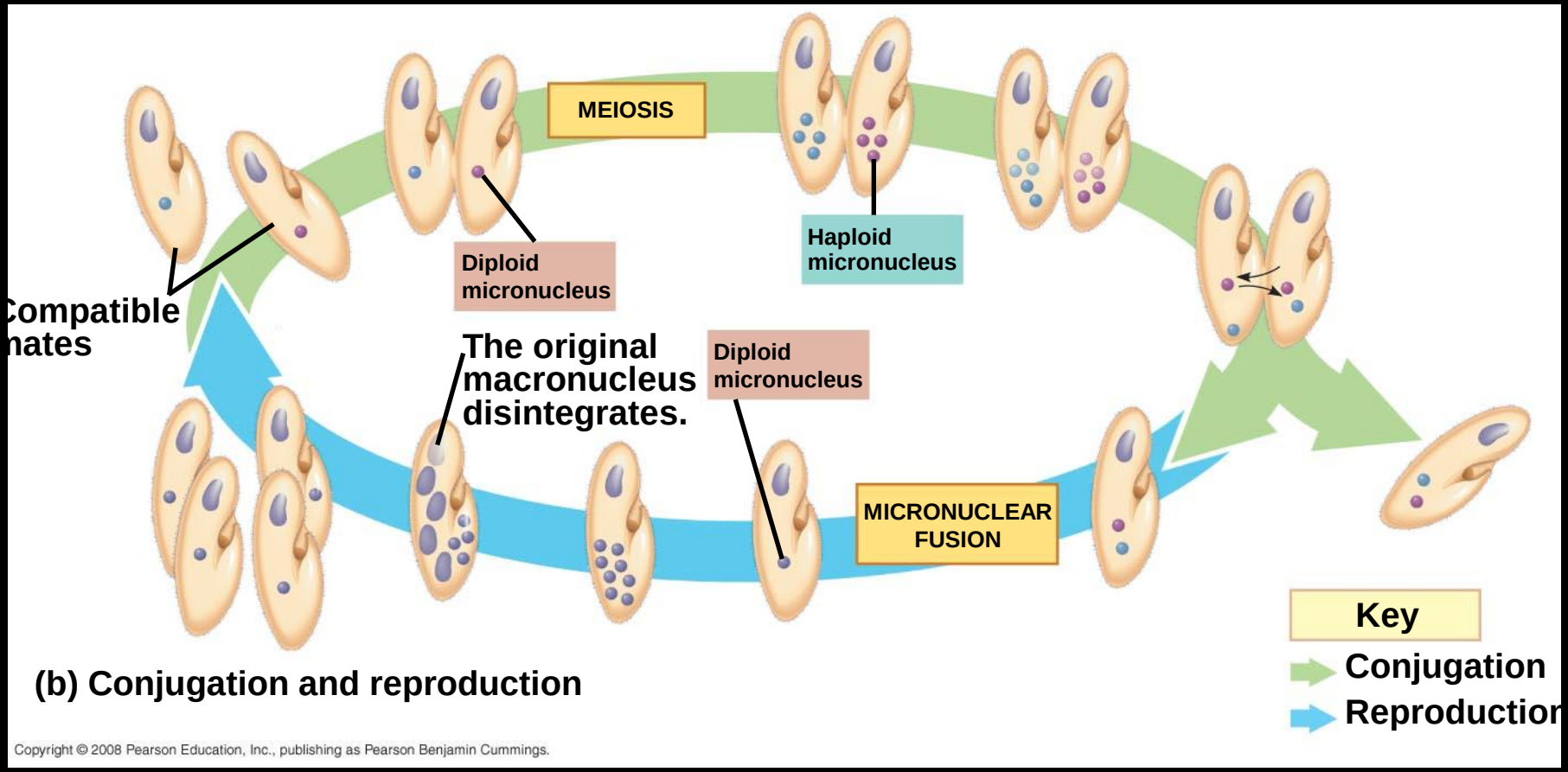


Ciliates

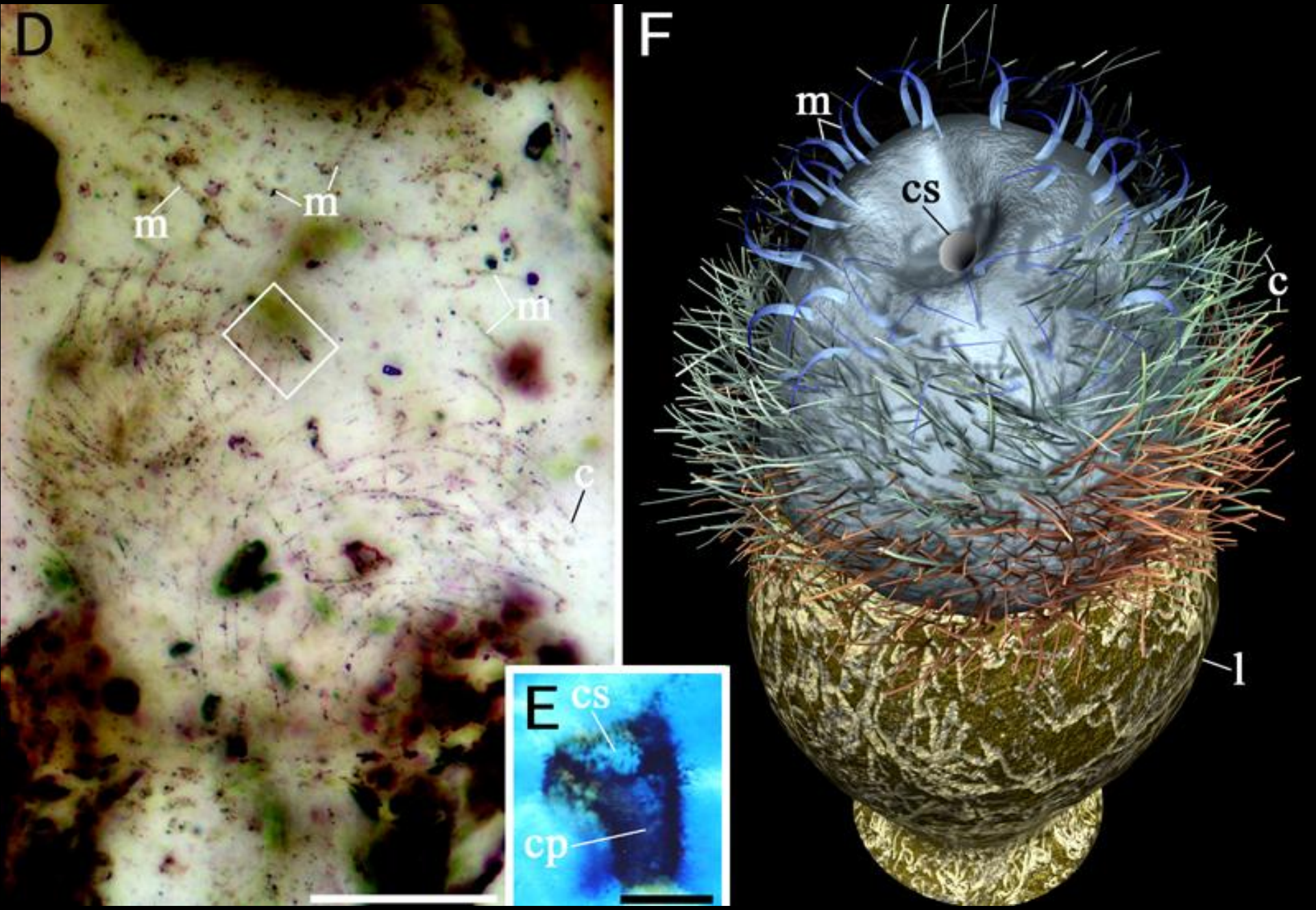
- **Ciliates**, a large varied group of protists, are named for their use of cilia to move and feed
- They have large macronuclei and small micronuclei
- The micronuclei function during conjugation, a sexual process that produces genetic variation
- Conjugation is separate from reproduction, which generally occurs by



(a) Feeding, waste removal, and water balance



(b) Conjugation and reproduction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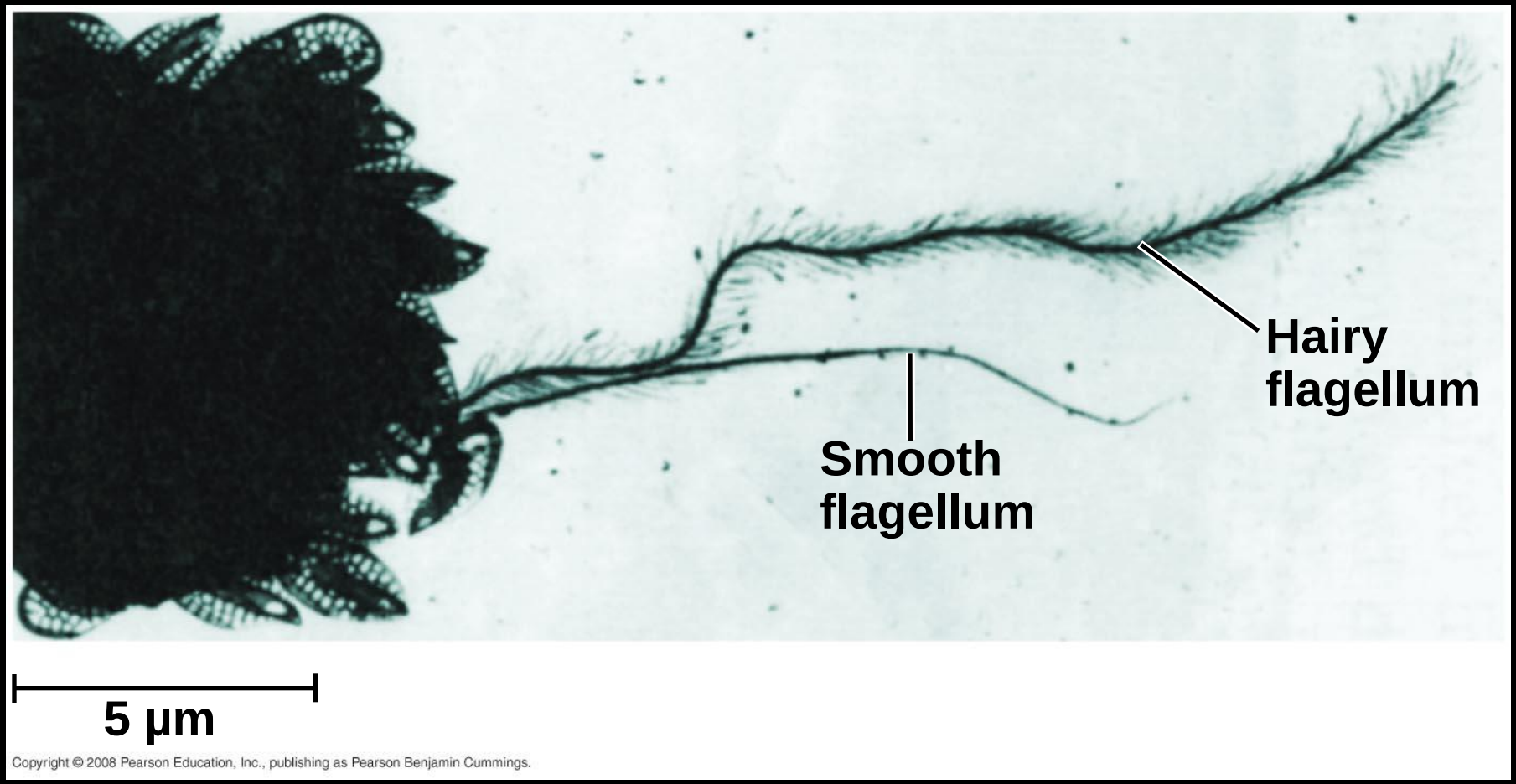
Stramenopiles

- The clade **Stramenopila** includes several groups of heterotrophs as well as certain groups of algae
- Most have a “hairy” flagellum paired with a “smooth” flagellum



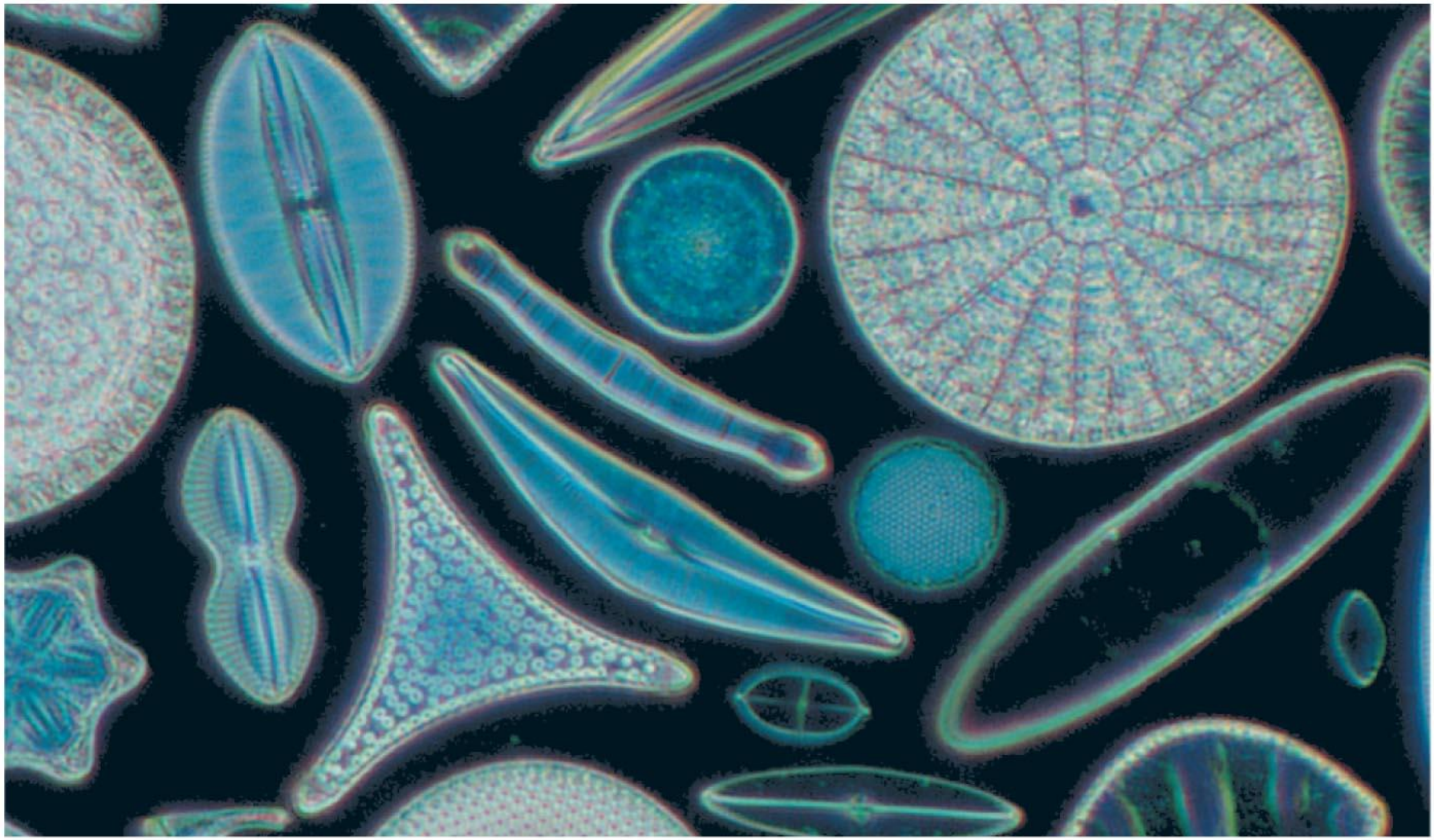
Diatoms

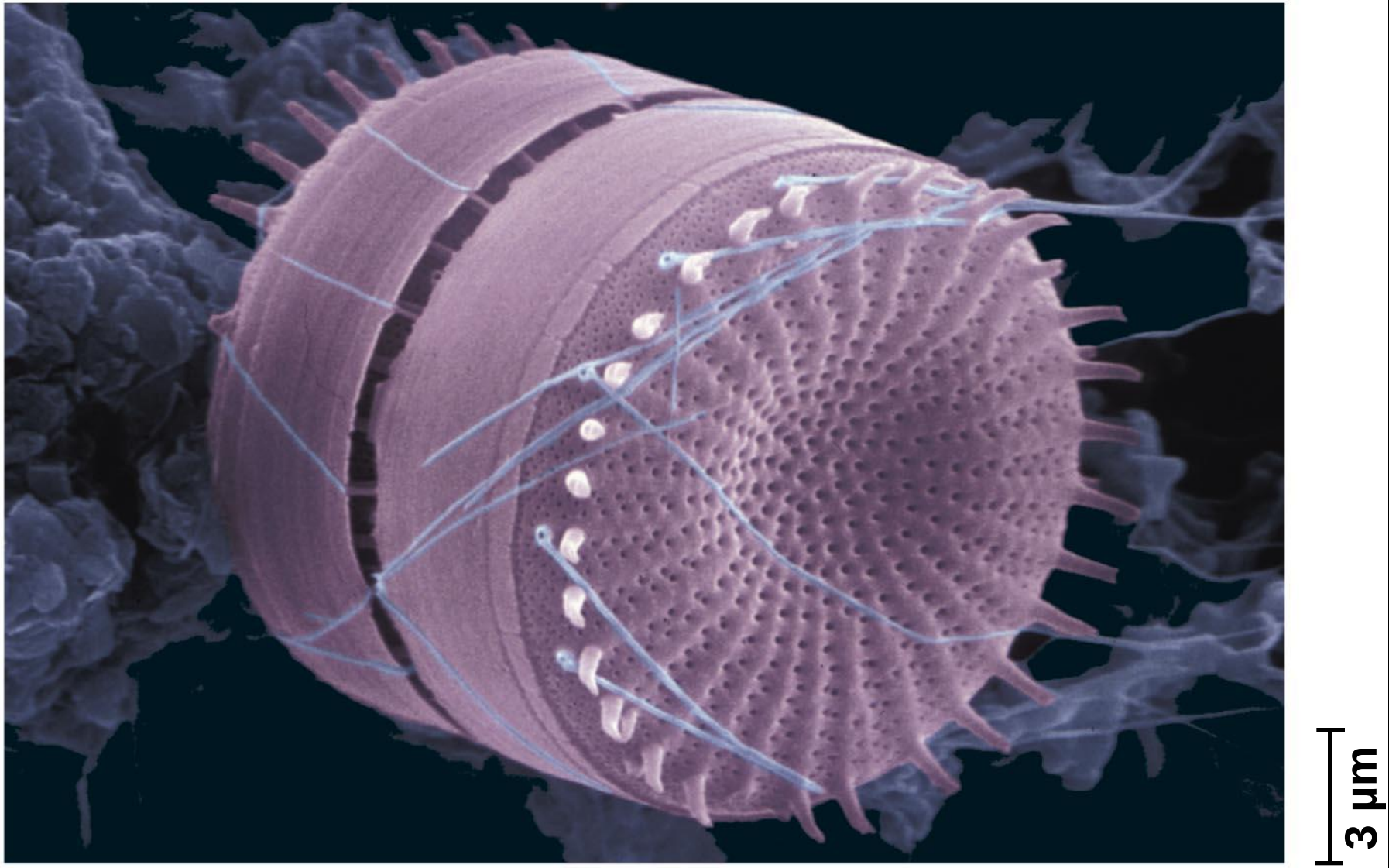
- **Diatoms** are unicellular algae with a unique two-part, glass-like wall of hydrated silica
- Diatoms usually reproduce asexually, and occasionally sexually

- Diatoms are a major component of phytoplankton and are highly diverse
- Fossilized diatom walls compose much of the sediments known as diatomaceous earth

PLAY Video: Diatoms Moving

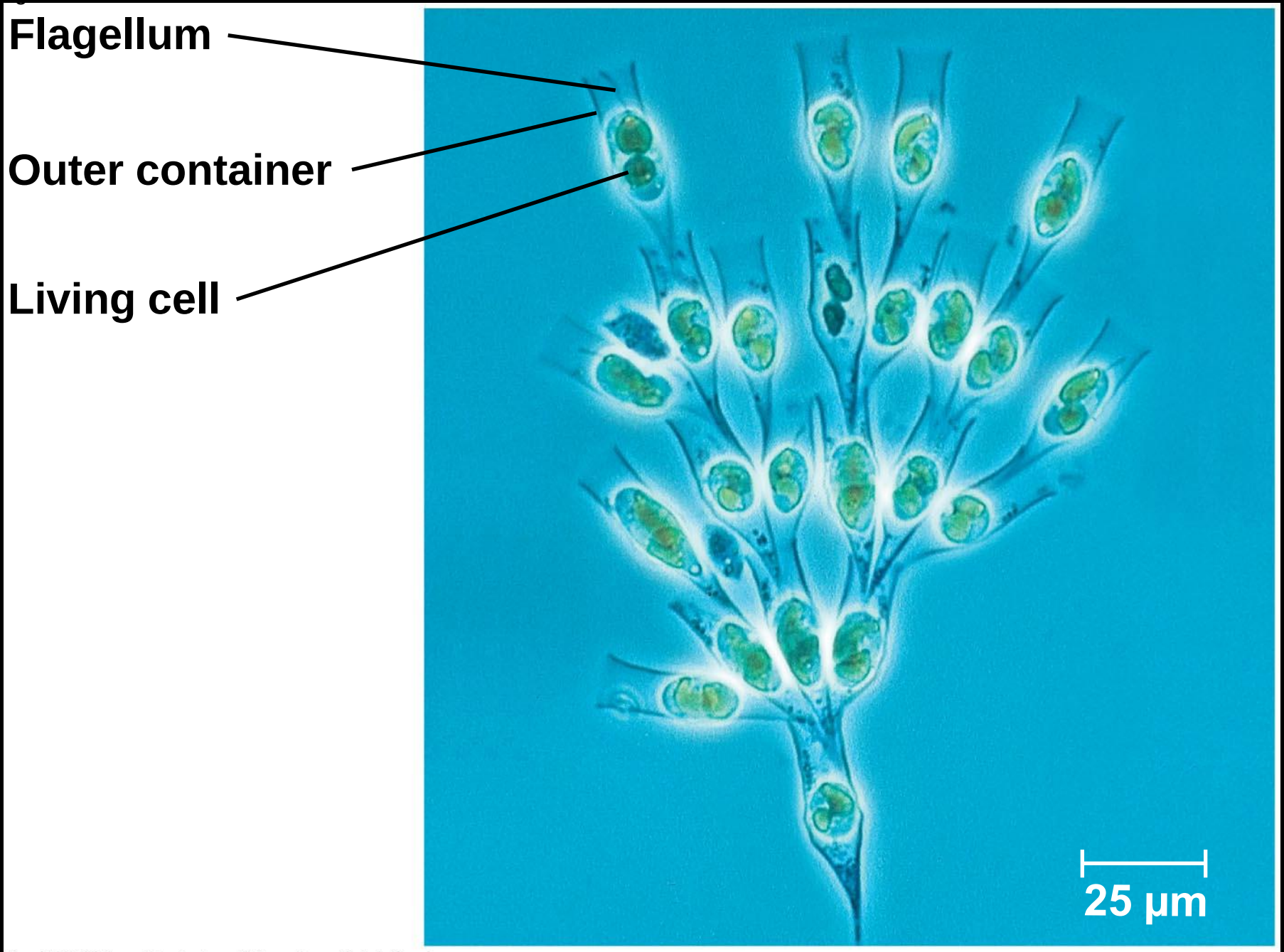
PLAY Video: Various Diatoms





Golden Algae

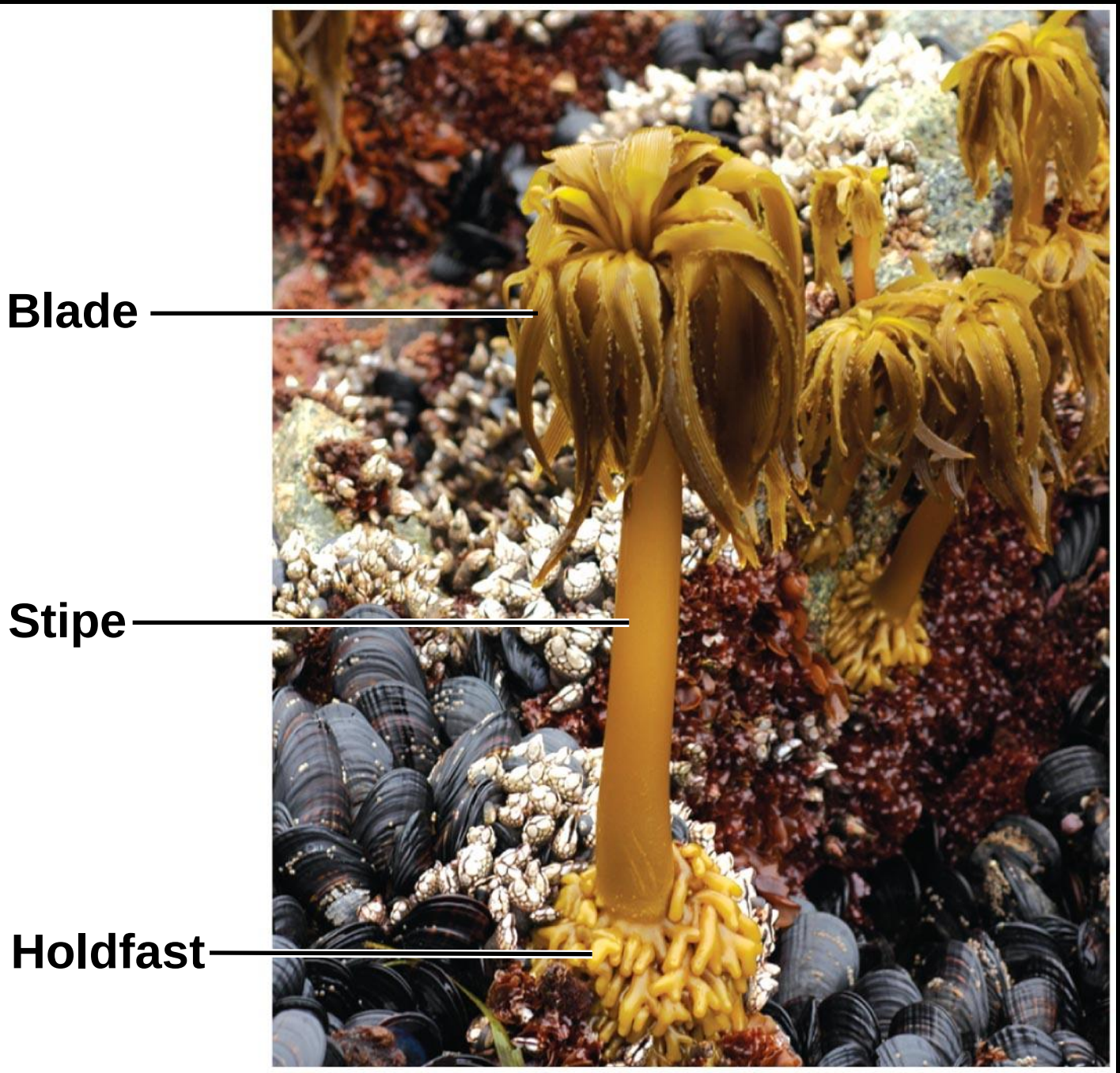
- **Golden algae** are named for their color, which results from their yellow and brown carotenoids
- The cells of golden algae are typically biflagellated, with both flagella near one end
- All golden algae are photosynthetic, and some are also heterotrophic
- Most are unicellular, but some are colonial



Brown Algae

- **Brown algae** are the largest and most complex algae
- All are multicellular, and most are marine
- Brown algae include many species commonly called “seaweeds”
- Brown algae have the most complex multicellular anatomy of all algae

- Giant seaweeds called kelps live in deep parts of the ocean
- The algal body is plantlike but lacks true roots, stems, and leaves and is called a **thallus**
- The rootlike **holdfast** anchors the stemlike **stipe**, which in turn supports the leaflike **blades**



Alternation of Generations

- A variety of life cycles have evolved among the multicellular algae
- The most complex life cycles include an **alternation of generations**, the alternation of multicellular haploid and diploid forms
- **Heteromorphic** generations are structurally different, while **isomorphic** generations look similar

10 cm

Sporangia

Sporophyte
(2*n*)

MEIOSIS

Zoospore

Female

Gametophytes
(*n*)

Male

Sperm

Egg

FERTILIZATION

Zygote
(2*n*)

Developing
sporophyte

Mature female
gemetophyte
(*n*)

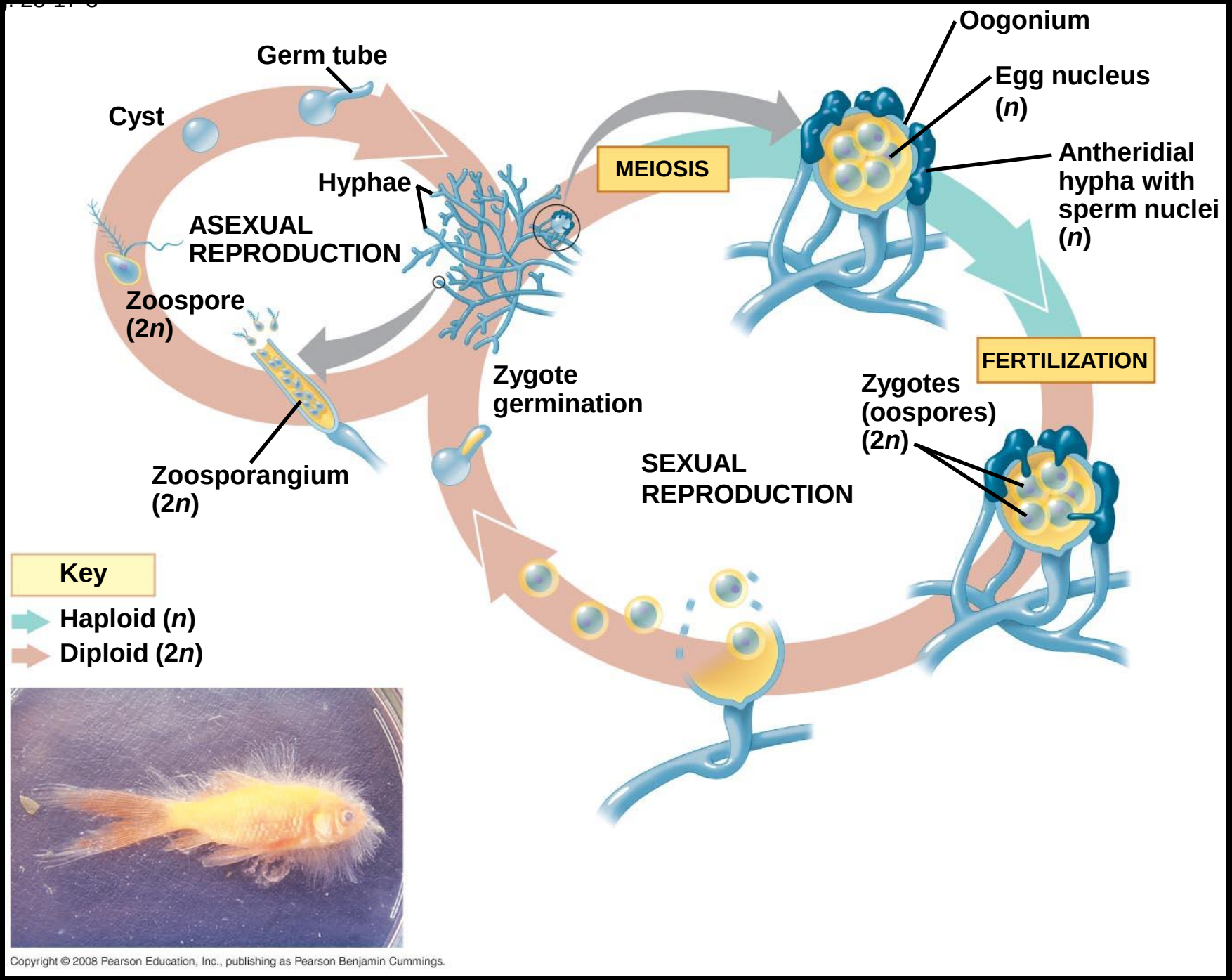
Key

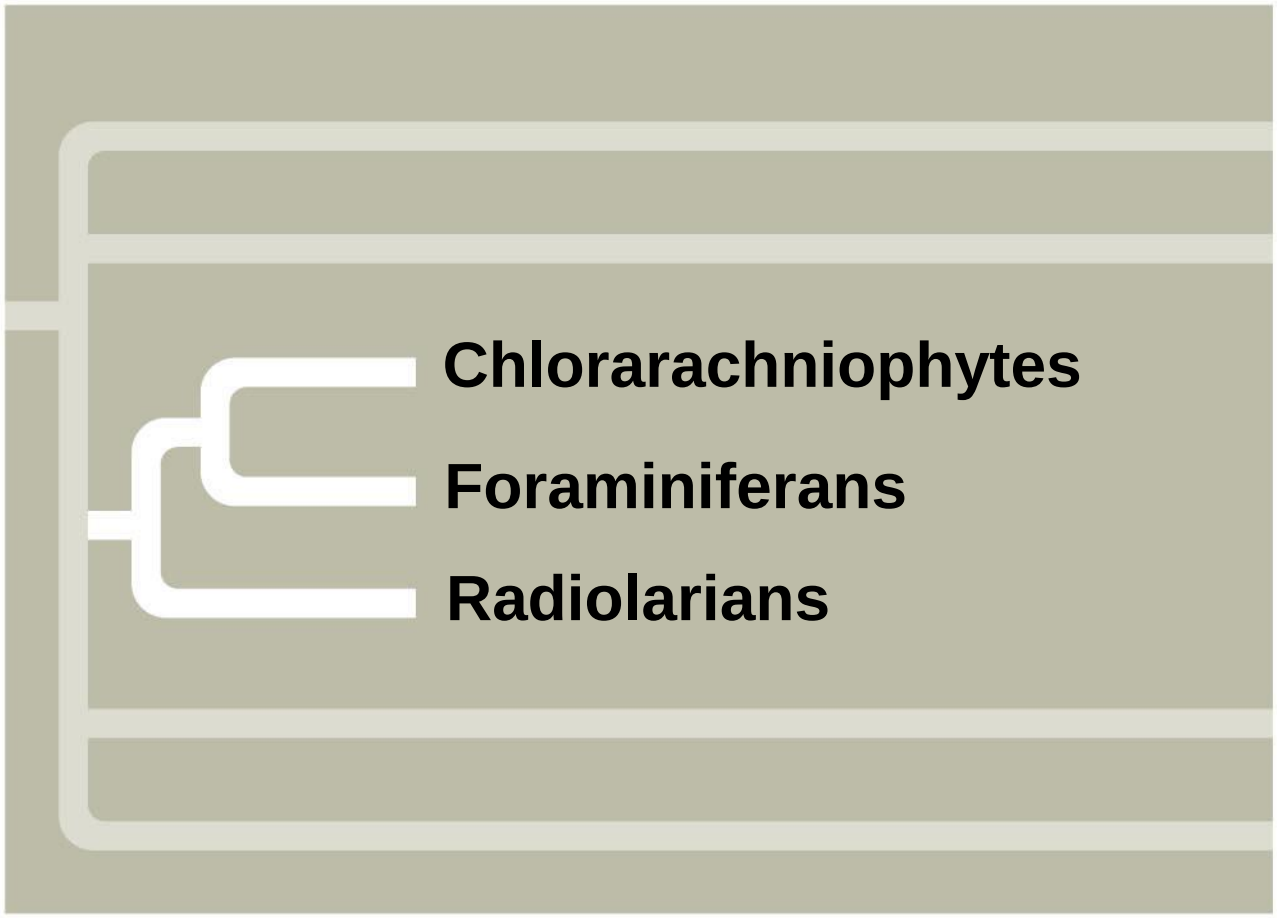
Haploid (*n*)

Diploid (2*n*)

Oomycetes (Water Molds and Their Relatives)

- **Oomycetes** include water molds, white rusts, and downy mildews
- They were once considered fungi based on morphological studies
- Most oomycetes are decomposers or parasites
- They have filaments (hyphae) that facilitate nutrient uptake
- Their ecological impact can be great, as in *Phytophthora infestans* causing potato





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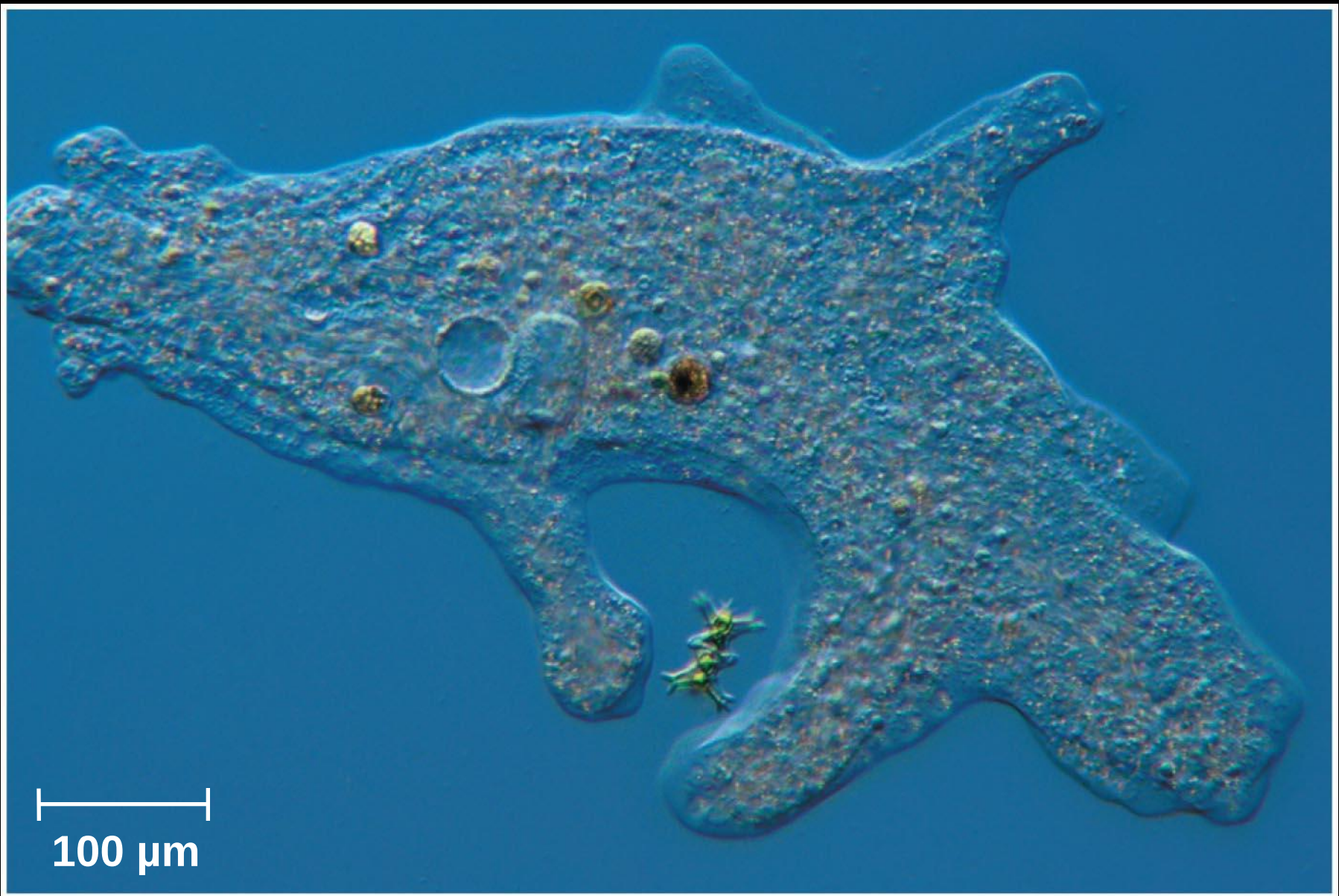
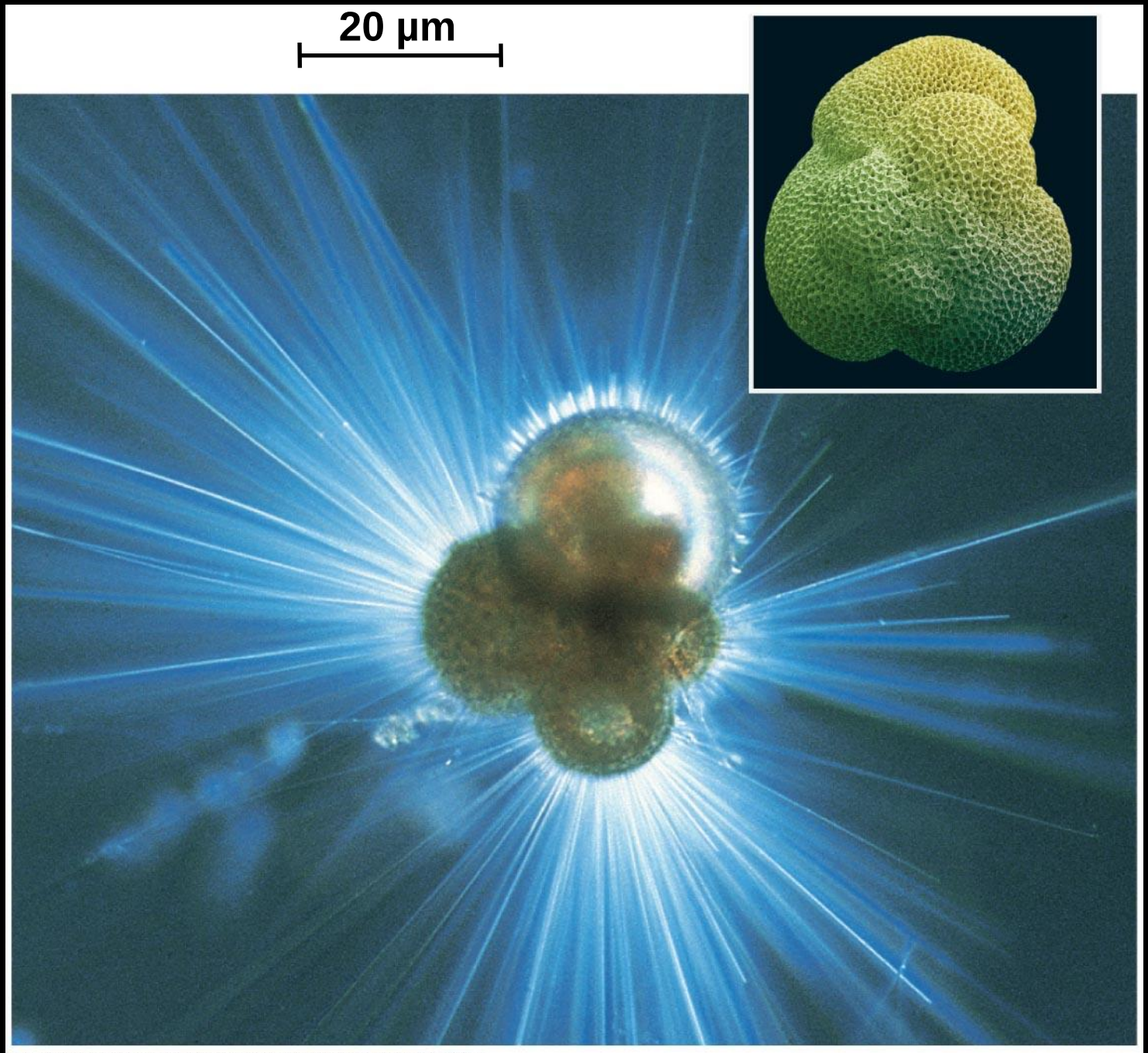
Archaeplastida

Unikonta



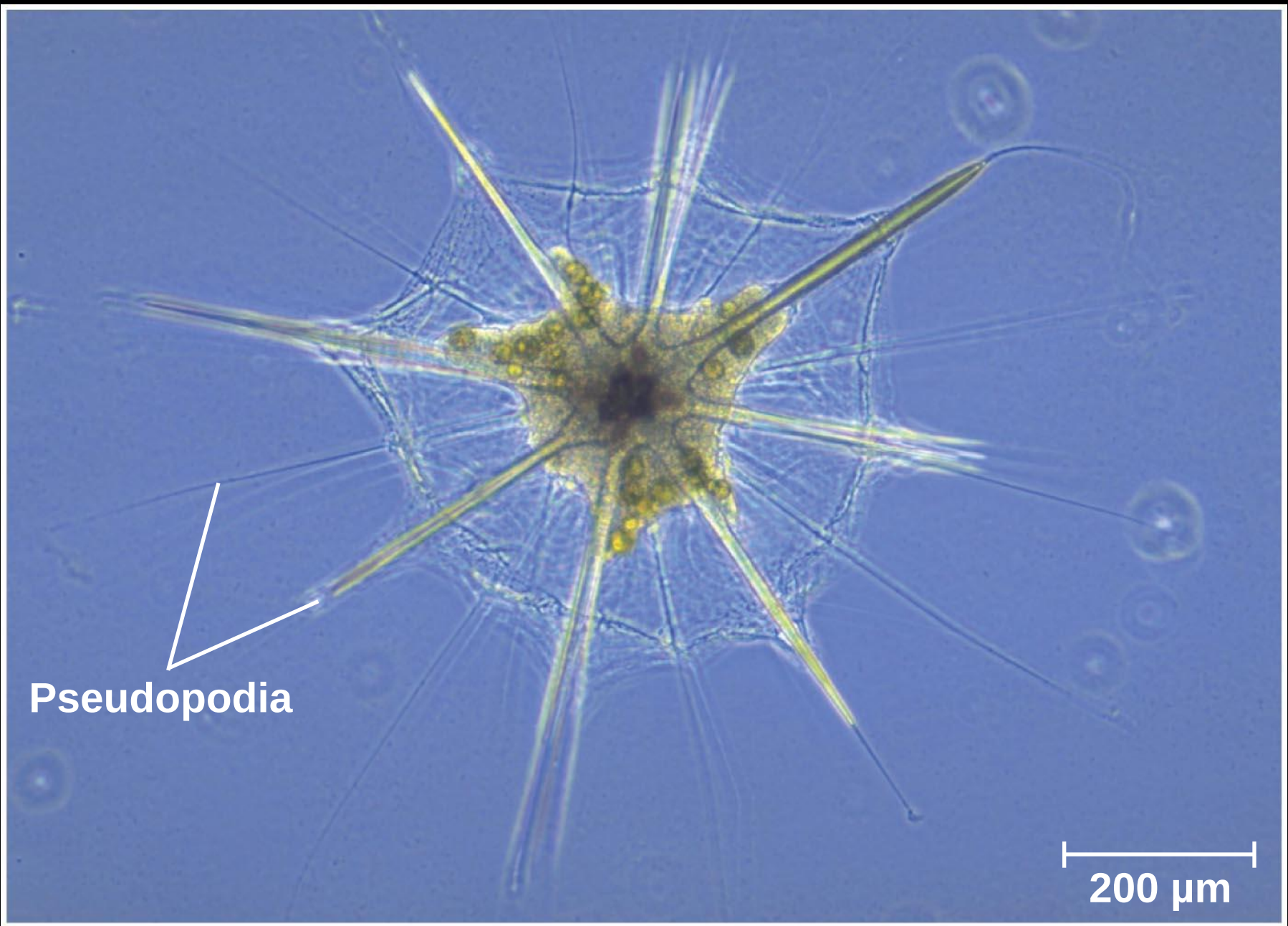
Forams

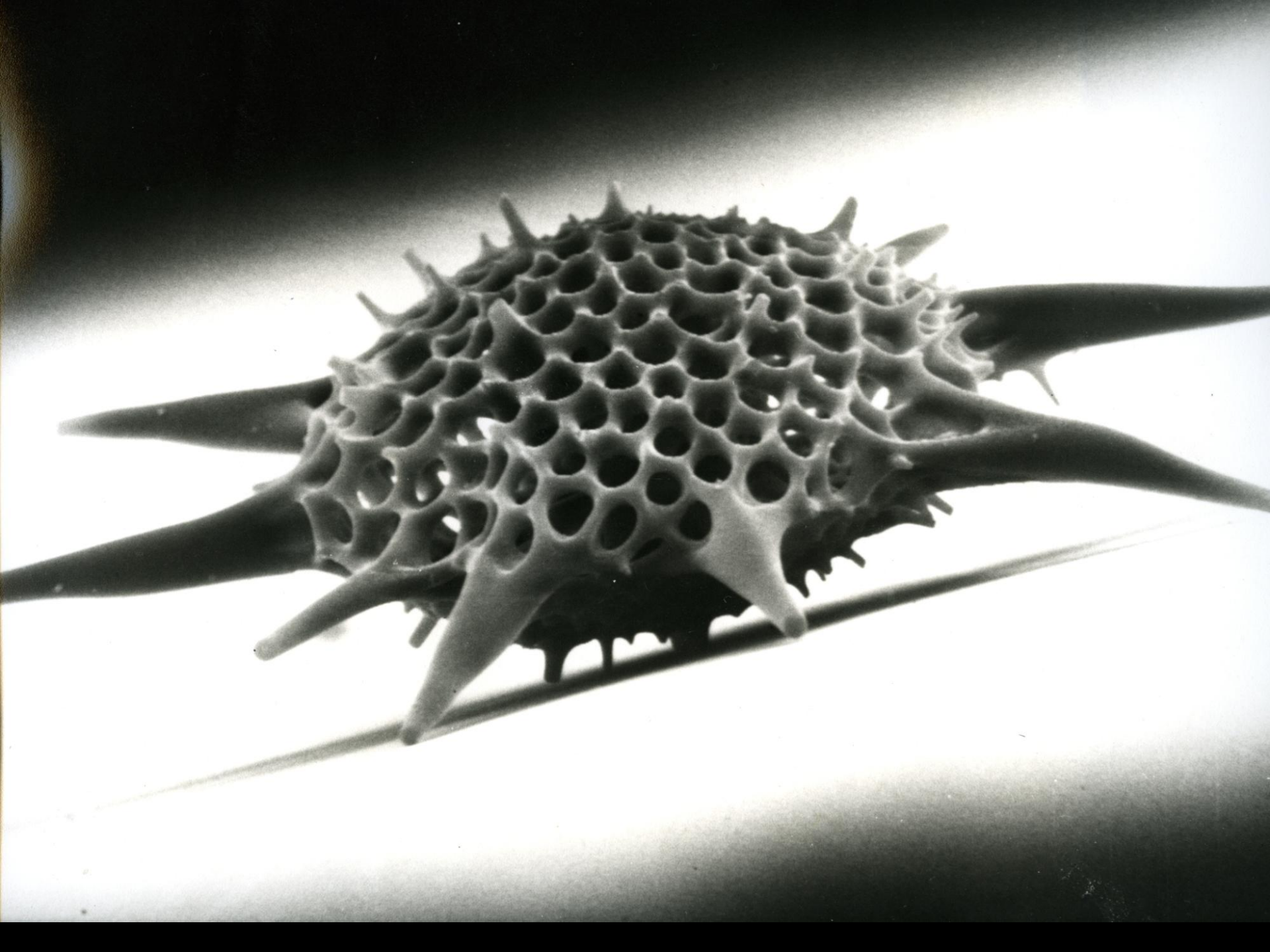
- **Foraminiferans**, or **forams**, are named for porous, generally multichambered shells, called **tests**
- Pseudopodia extend through the pores in the test
- Foram tests in marine sediments form an extensive fossil record

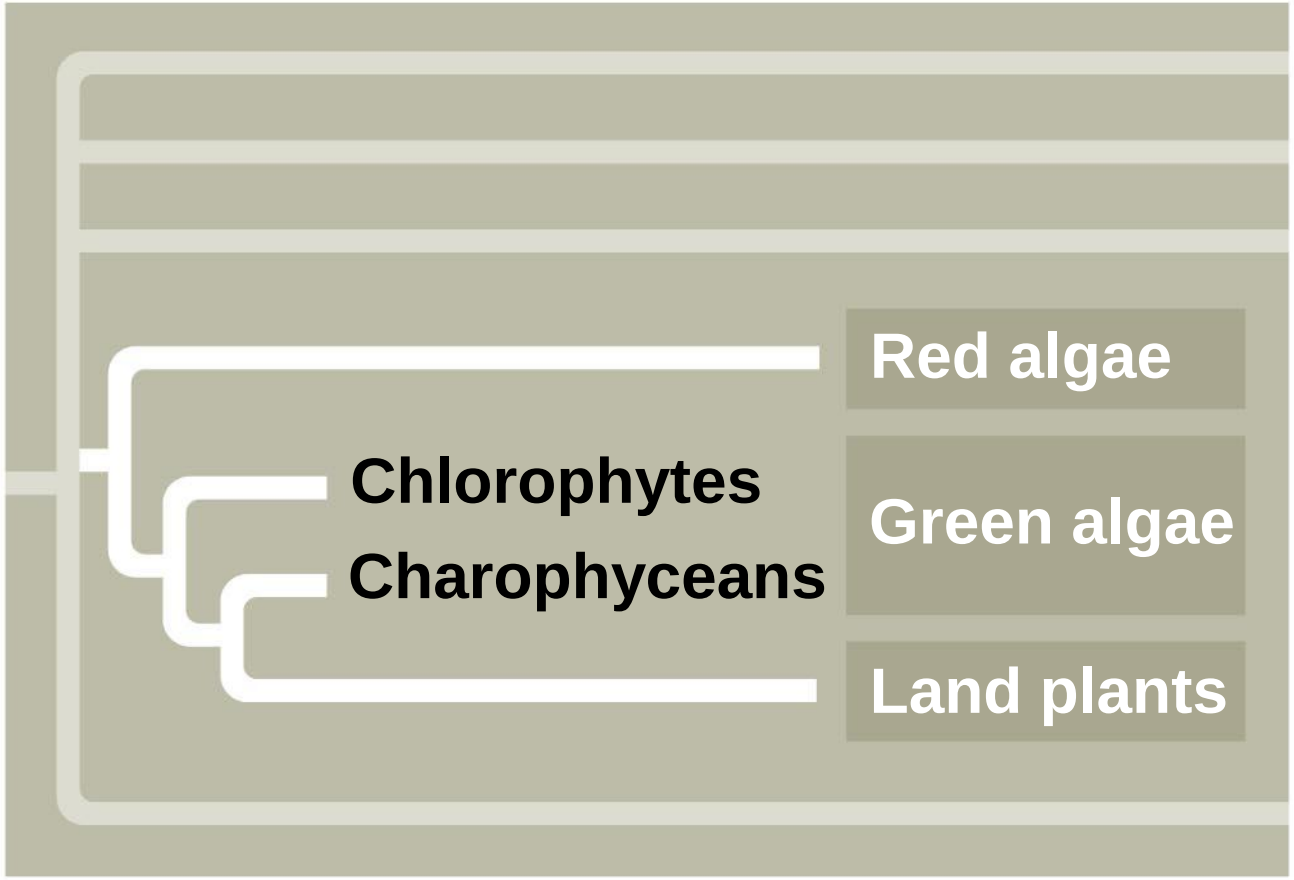


Radiolarians

- Marine protists called **radiolarians** have tests fused into one delicate piece, usually made of silica
- Radiolarians use their pseudopodia to engulf microorganisms through phagocytosis
- The pseudopodia of radiolarians radiate from the central body







Excavata

Chromalveolata

Rhizaria

Archaeplastida

Unikonta

Red Algae

- **Red algae** are reddish in color due to an accessory pigment call phycoerythrin, which masks the green of chlorophyll
- The color varies from greenish-red in shallow water to dark red or almost black in deep water
- Red algae are usually multicellular; the largest are seaweeds
- Red algae are the most abundant large algae in coastal waters of the tropics

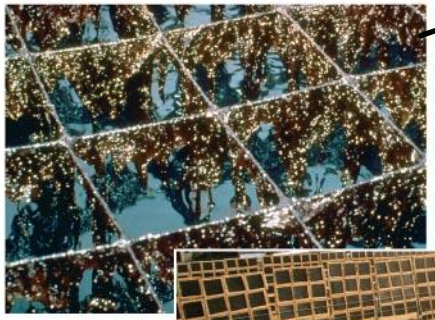
▶ ***Bonnemaisonia hamifera***

20 cm

8 mm

◀ **Dulse (*Palmaria palmata*)**

▼ **Nori. The red alga *Porphyra* is the source of a traditional Japanese food.**

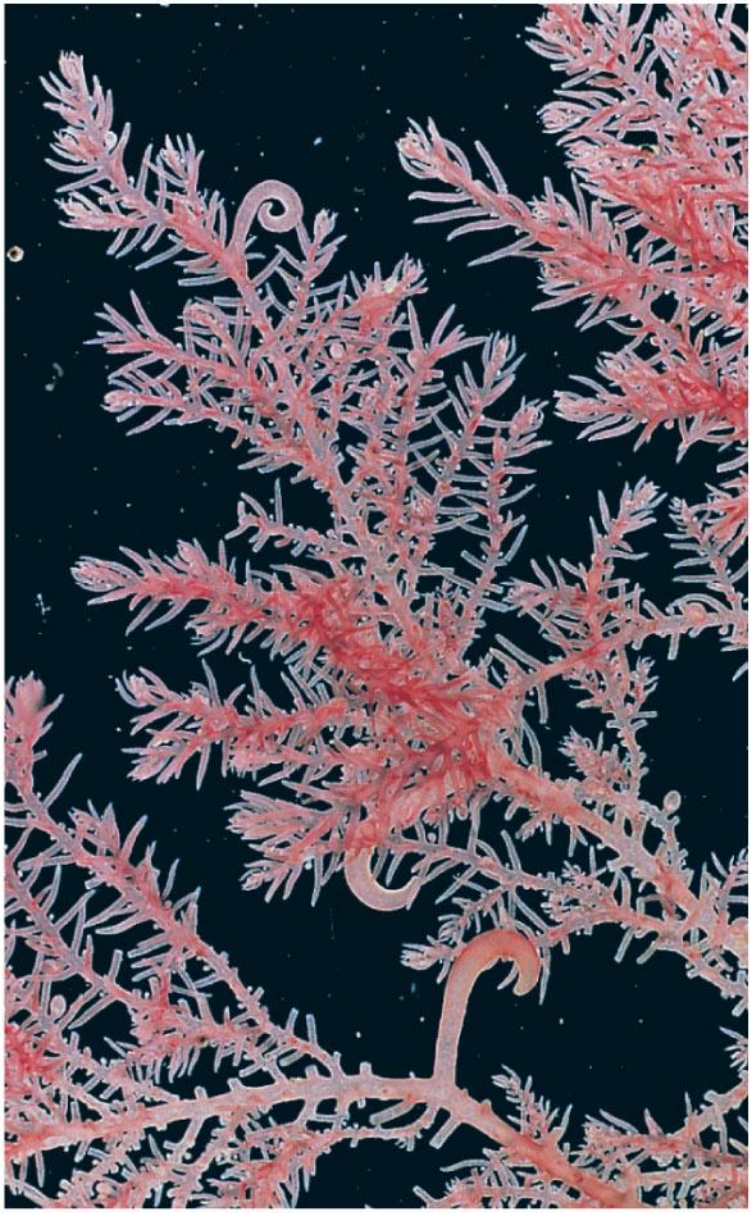


The seaweed is grown on nets in shallow coastal waters.

The harvested seaweed is spread on bamboo screens to dry.

Paper-thin, glossy sheets of nori make a mineral-rich wrap for rice, seafood, and vegetables in sushi.

- ***Bonnemaisonia hamifera***



8 mm

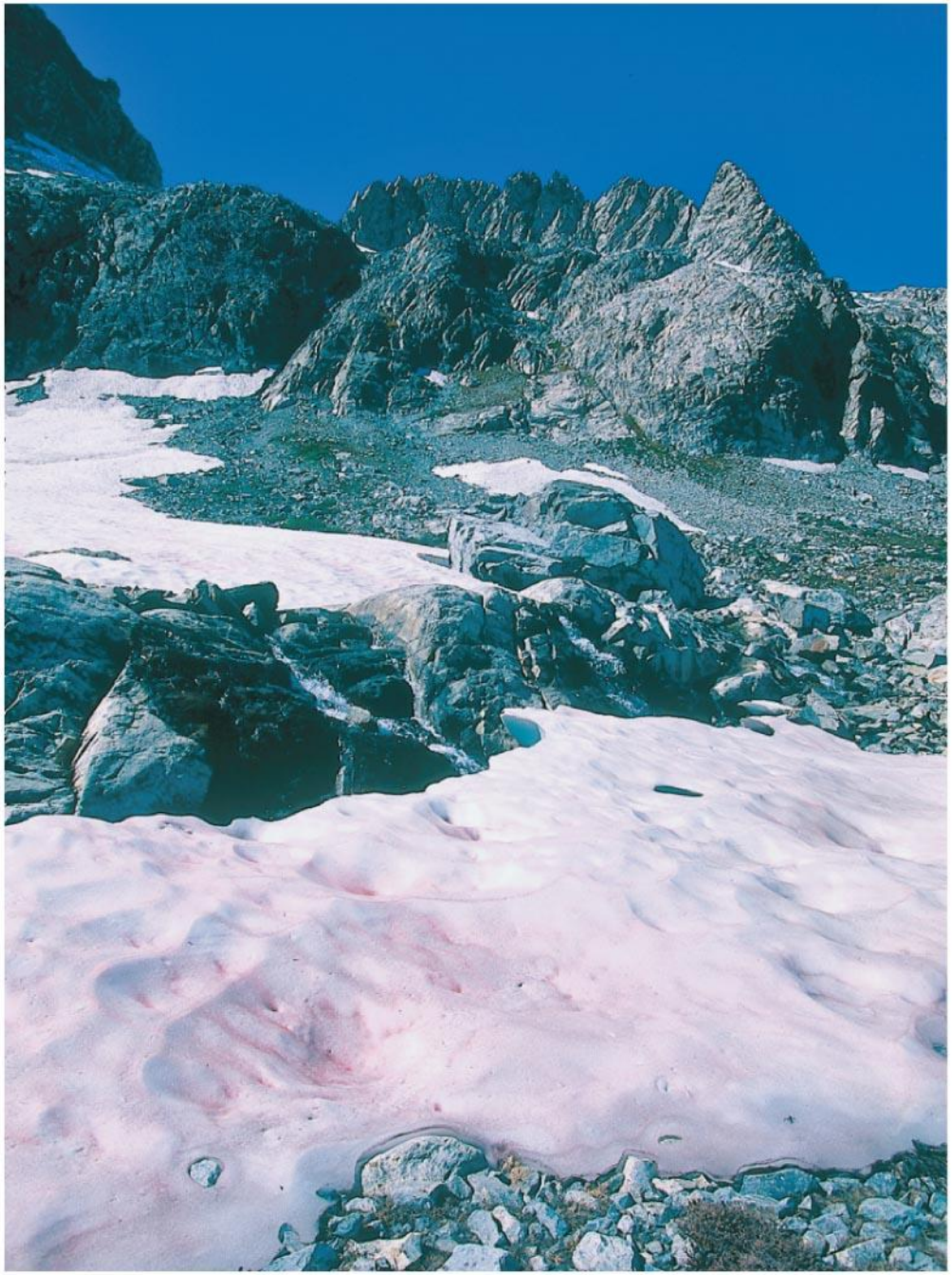
20 cm

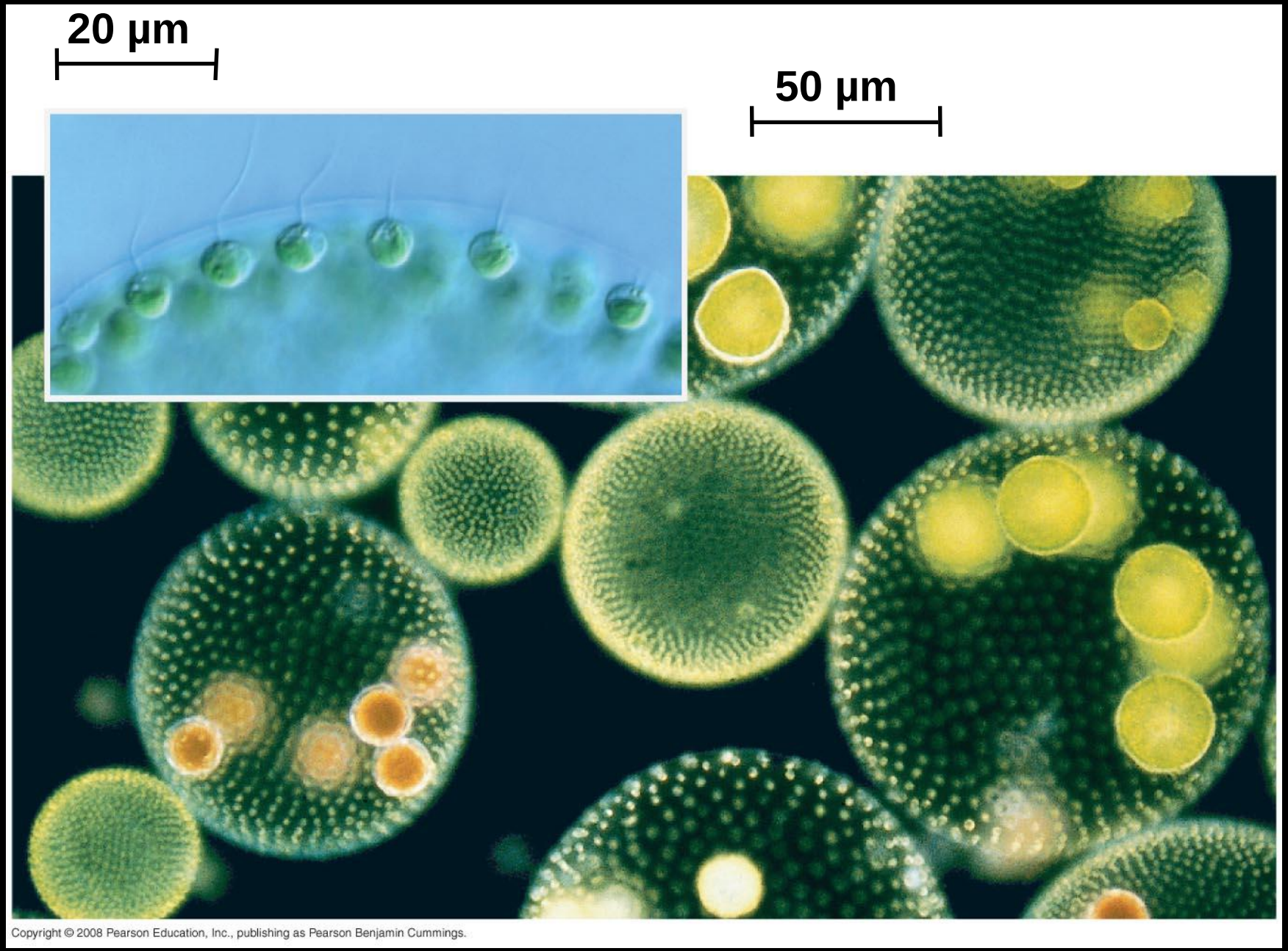
◀ **Dulse (*Palmaria palmata*)**

Green Algae

- **Green algae** are named for their grass-green chloroplasts
- Plants are descended from the green algae
- The two main groups are chlorophytes and charophyceans

- Most chlorophytes live in fresh water, although many are marine
- Other chlorophytes live in damp soil, as symbionts in lichens, or in snow





(a) *Ulva*, or sea lettuce

2 cm

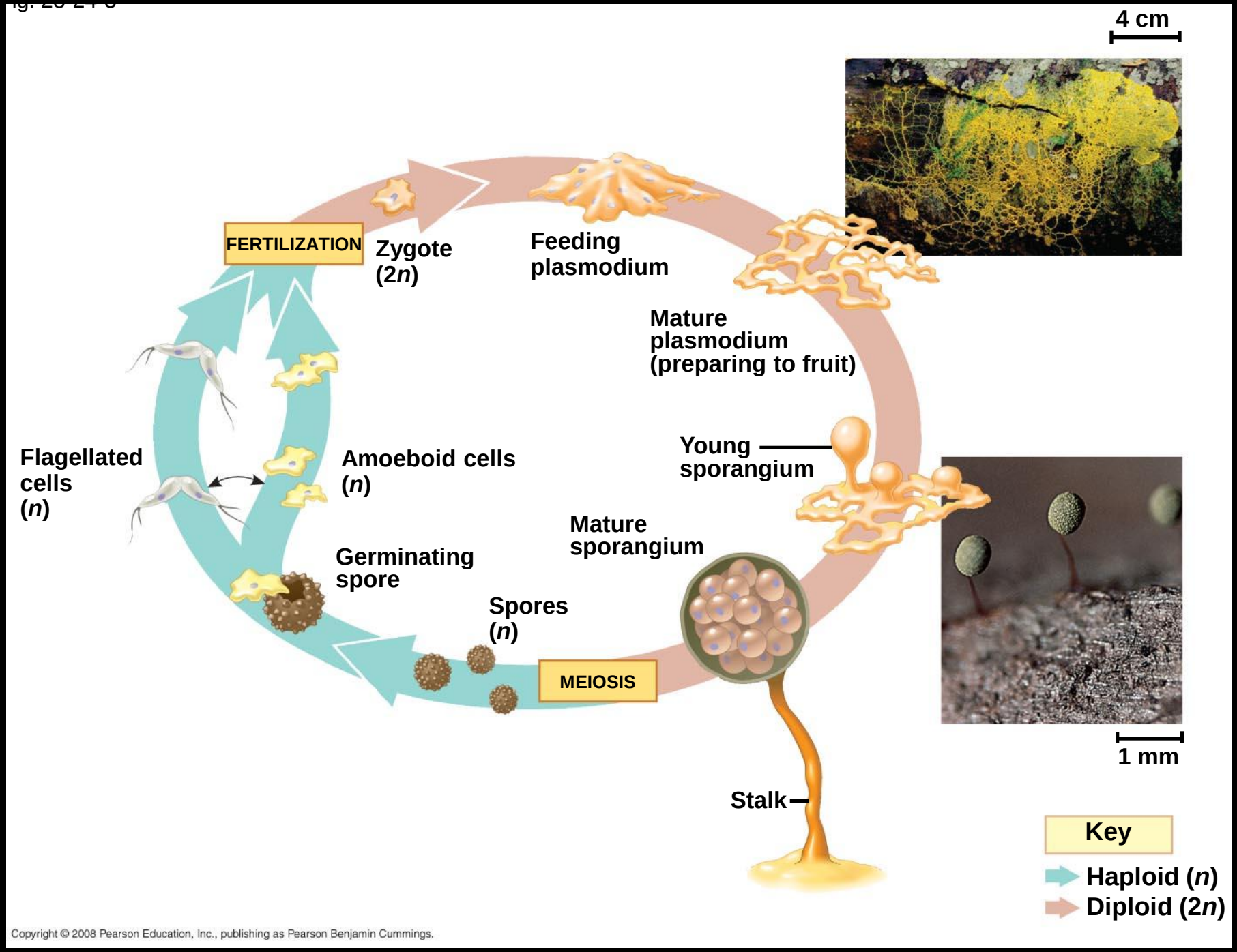
(b) *Caulerpa,* an intertidal chlorophyte

Plasmodial Slime Molds

- Many species of **plasmodial slime molds** are brightly pigmented, usually yellow or orange

PLAY Video: Plasmodial Slime Mold

PLAY Video: Plasmodial Slime Mold Streaming



Cellular Slime Molds

- **Cellular slime molds** form multicellular aggregates in which cells are separated by their membranes
- Cells feed individually, but can aggregate to form a fruiting body
- *Dictyostelium discoideum* is an experimental model for studying the evolution of multicellularity