Chapter 28

Protists

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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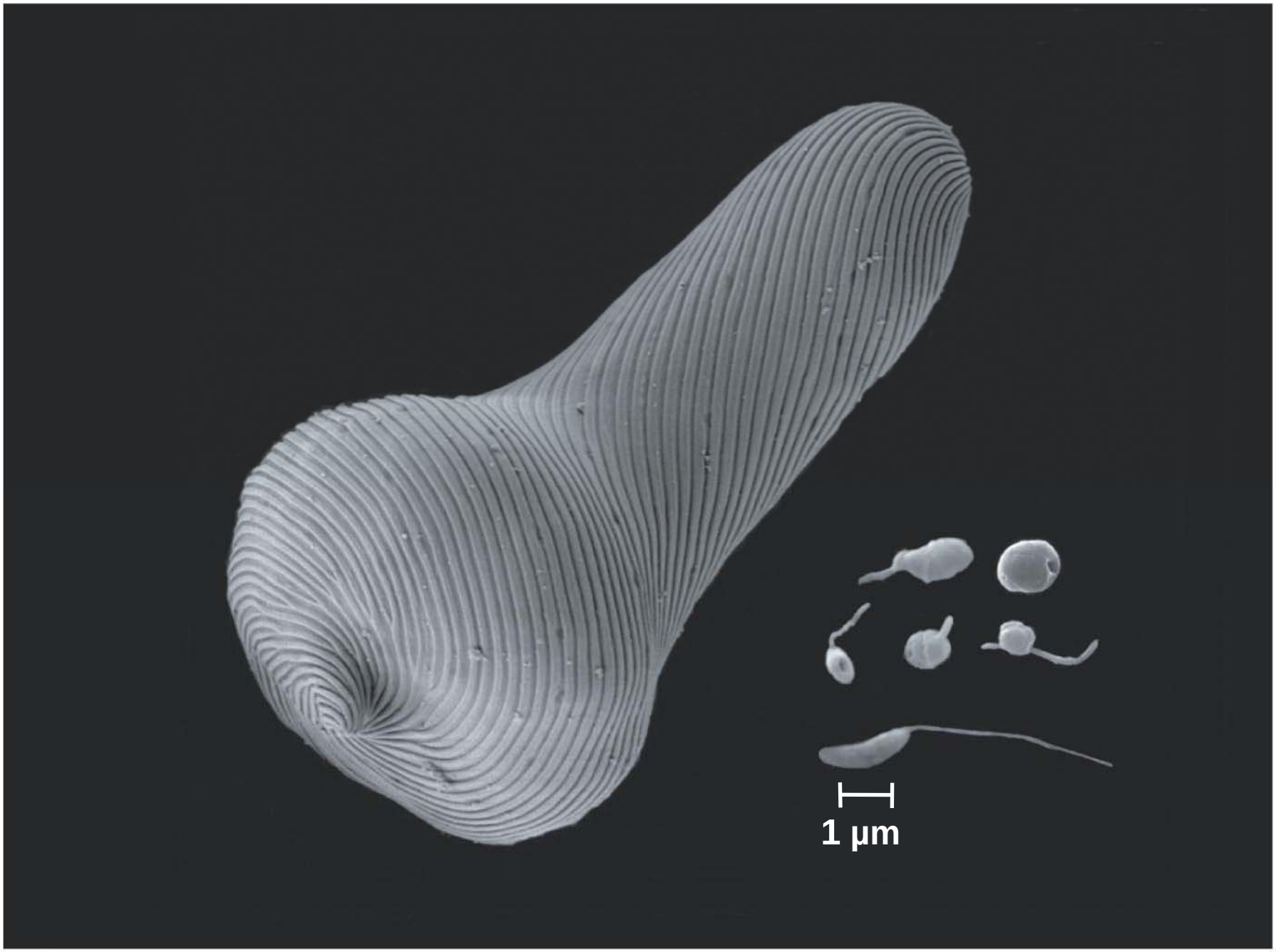
Overview: Living Small

- Even a low-power microscope can reveal a great variety of organisms in a drop of pond water
- **Protist** is the informal name of the kingdom of mostly unicellular eukaryotes
- Advances in eukaryotic systematics have caused the classification of protists to change significantly
- Protists constitute a paraphyletic group, and Protista is no longer valid as a kingdom

Fig. 28-01



Concept 28.1: Most eukaryotes are single-celled organisms

- Protists are eukaryotes and thus have organelles and are more complex than prokaryotes
- Most protists are unicellular, but there are some colonial and multicellular species

Structural and Functional Diversity in Protists

- Protists exhibit more structural and functional diversity than any other group of eukaryotes
- Single-celled protists can be very complex, as all biological functions are carried out by organelles in each individual cell

- Protists, the most nutritionally diverse of all eukaryotes, include:
  - Photoautotrophs, which contain chloroplasts
  - Heterotrophs, which absorb organic molecules or ingest larger food particles
  - **Mixotrophs**, which combine photosynthesis and heterotrophic nutrition

- Protists can reproduce asexually or sexually, or by the sexual processes of meiosis and syngamy

Endosymbiosis in Eukaryotic Evolution

- There is now considerable evidence that much protist diversity has its origins in endosymbiosis
- Mitochondria evolved by endosymbiosis of an aerobic prokaryote
- Plastids evolved by endosymbiosis of a photosynthetic cyanobacterium

Fig. 28-02-1

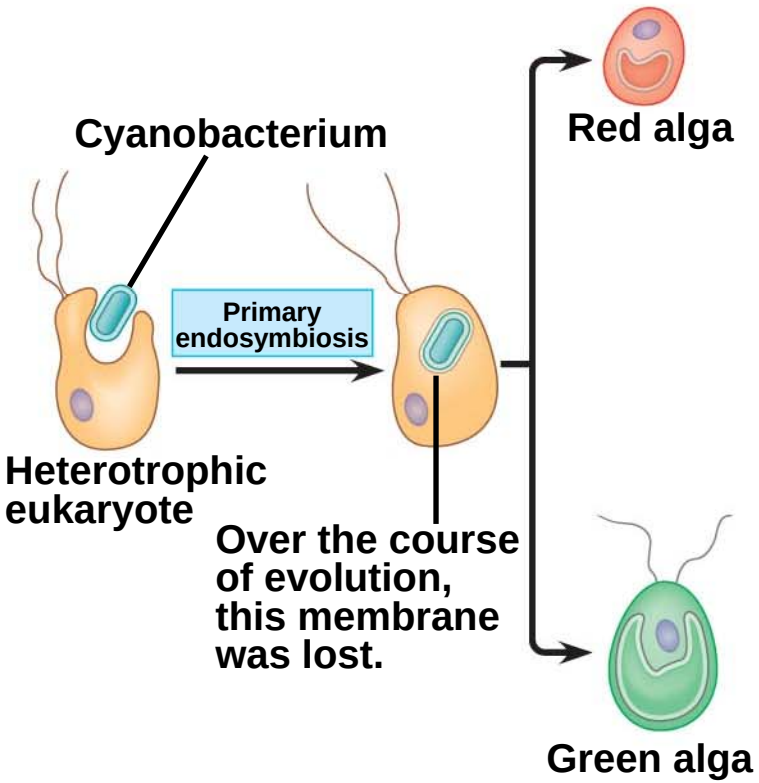
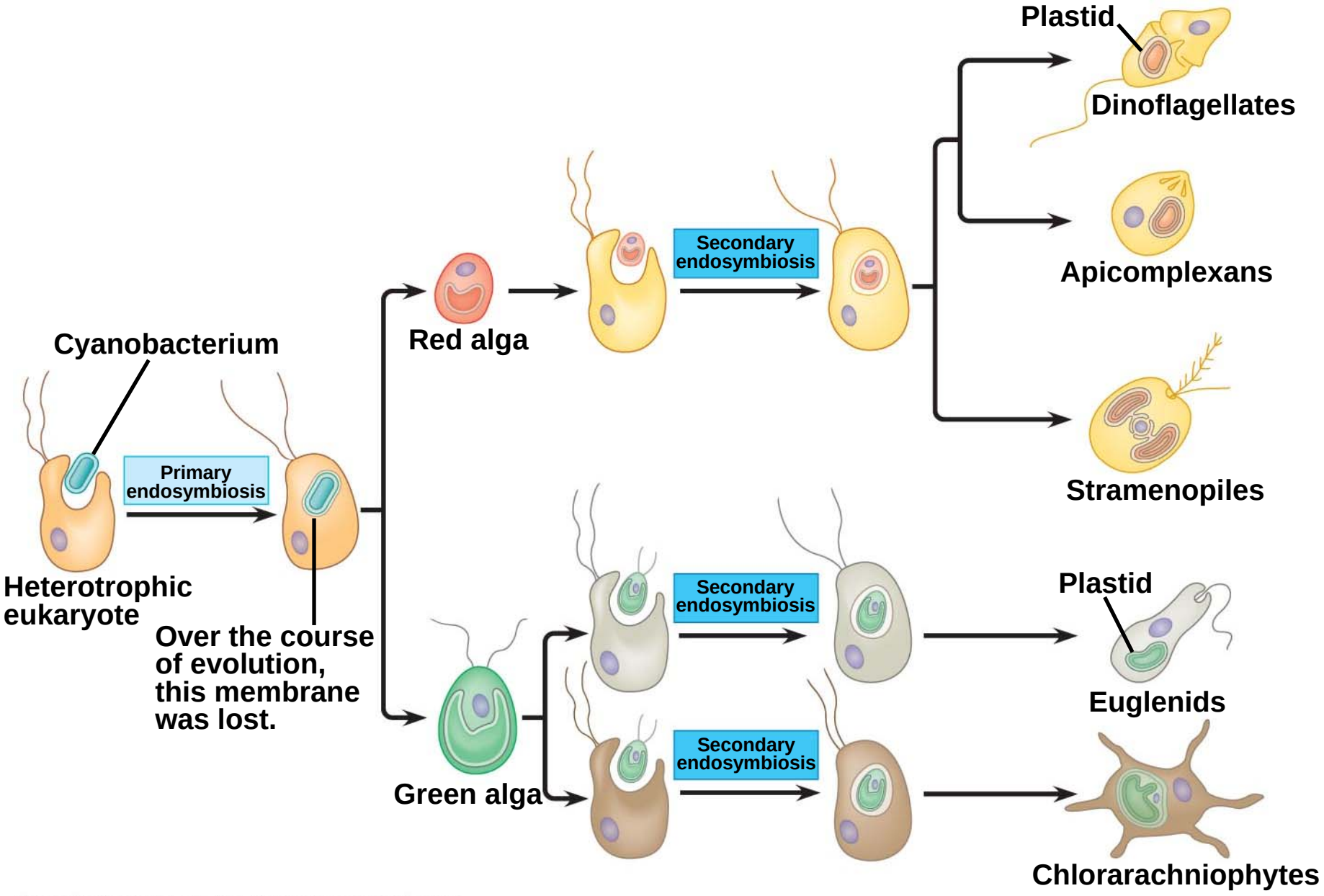


Fig. 28-02-2



- The plastid-bearing lineage of protists evolved into red algae and green algae
- On several occasions during eukaryotic evolution, red and green algae underwent **secondary endosymbiosis**, in which they were ingested by a heterotrophic eukaryote

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

Fig. 28-03a

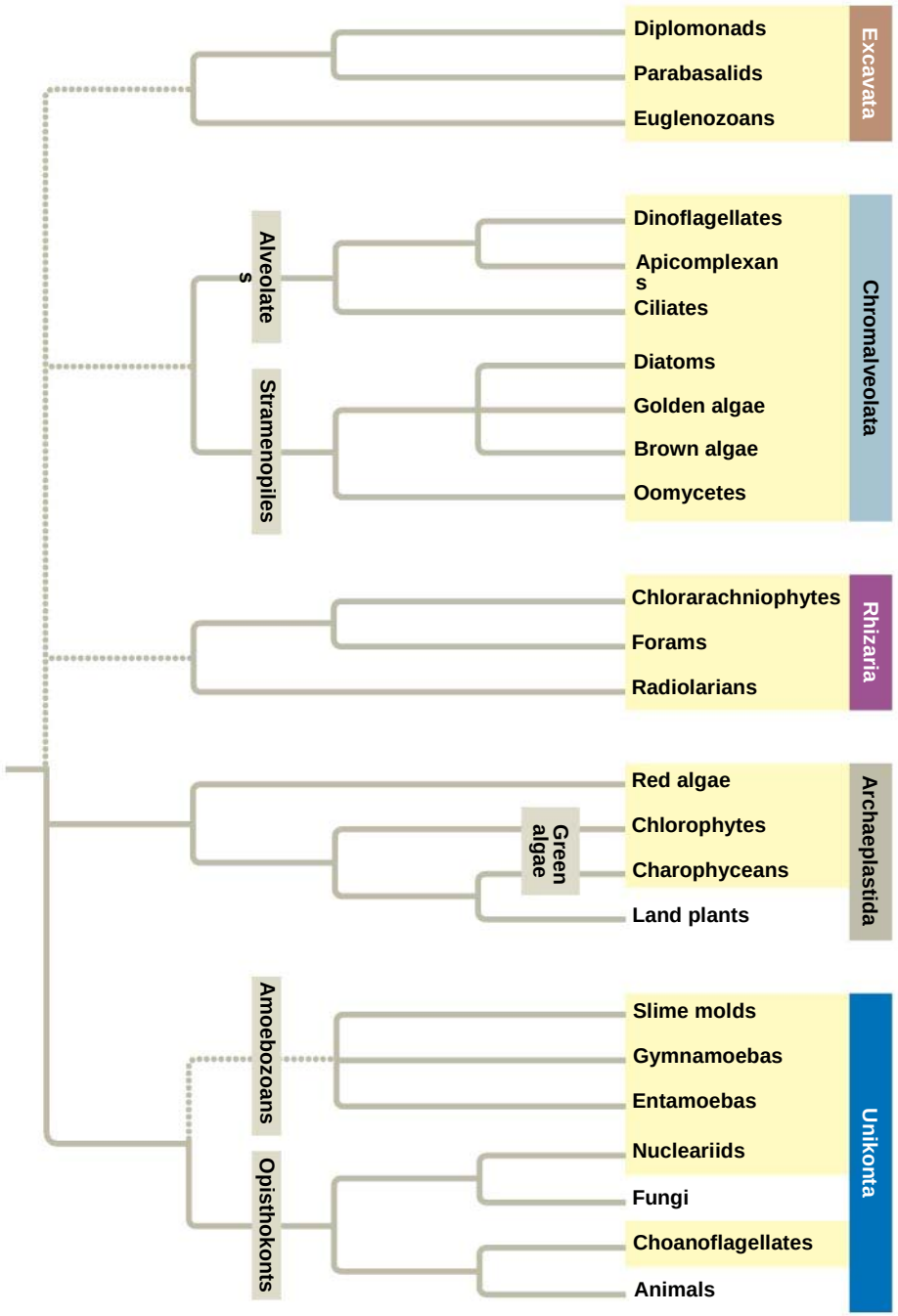


Fig. 28-03b

Fig. 28-03c

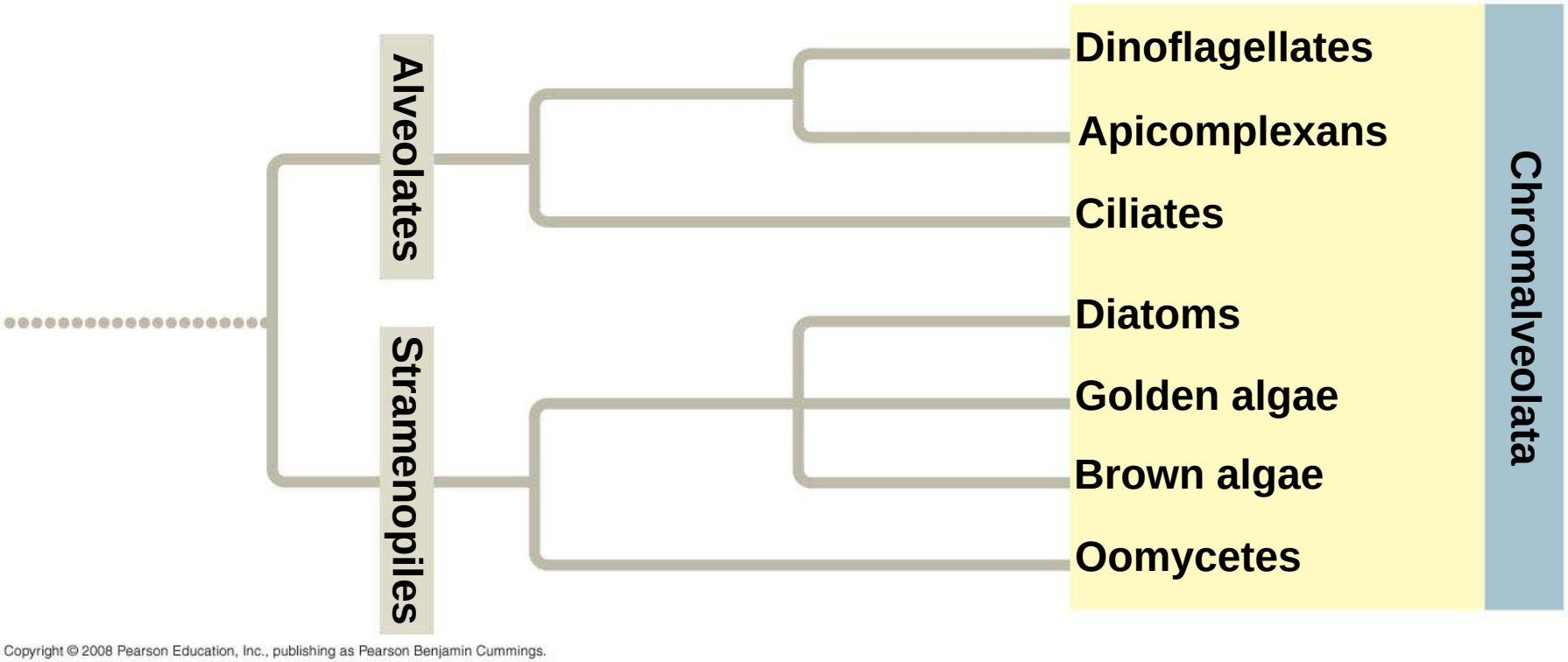


Fig. 28-03d

Fig. 28-03e

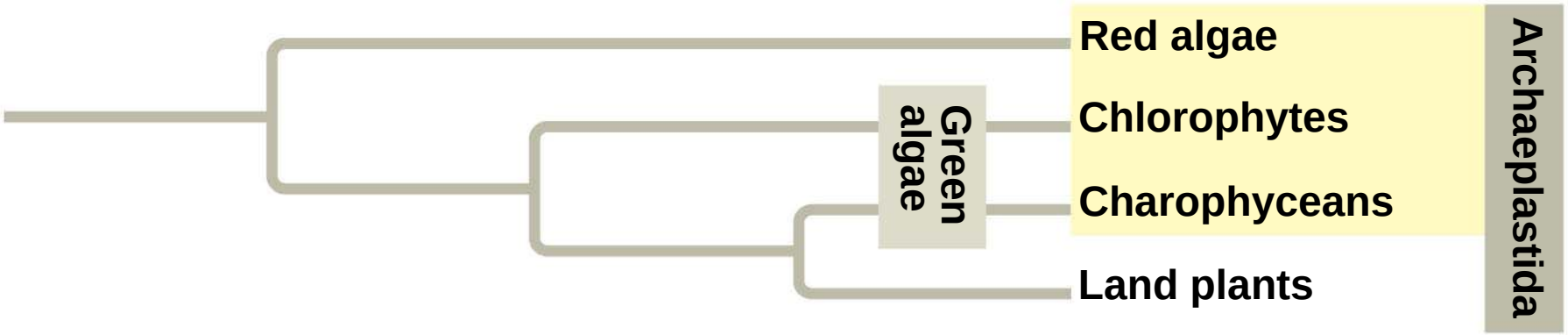


Fig. 28-03f

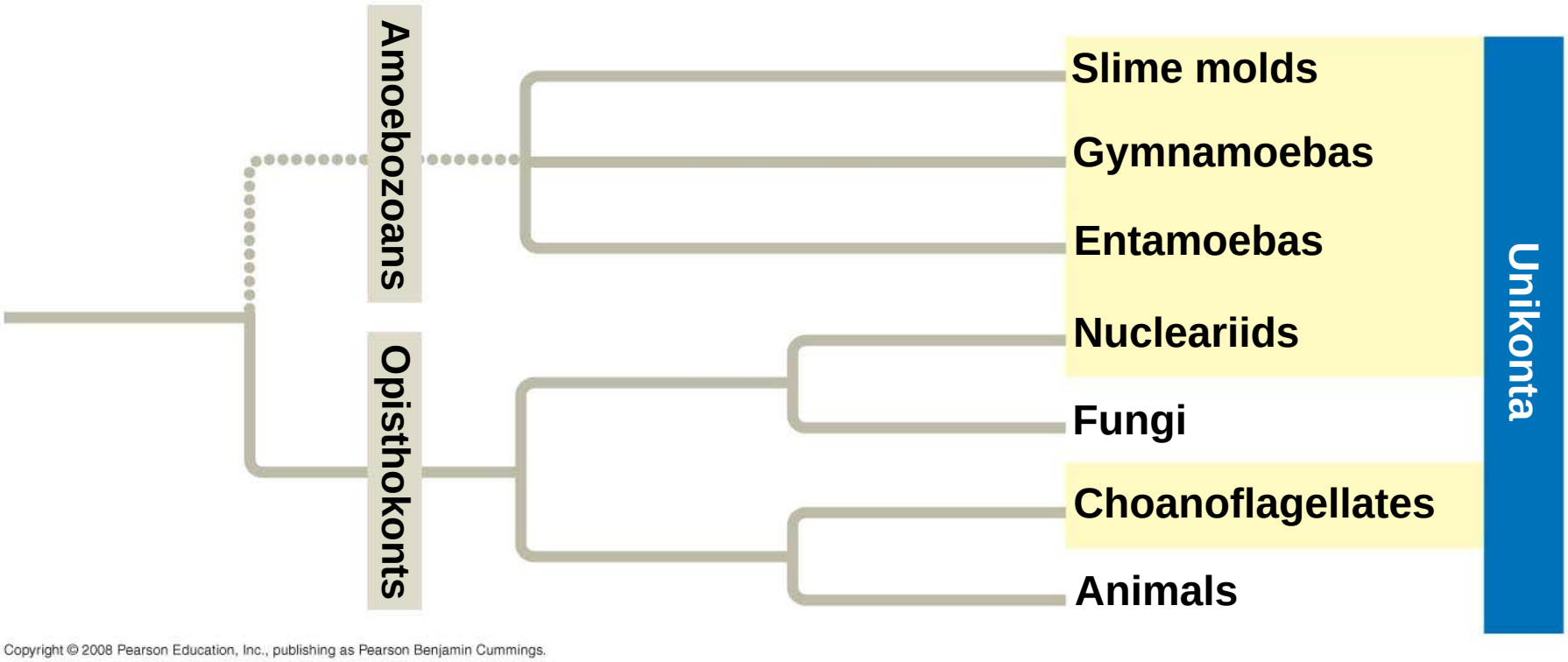


Fig. 28-03g

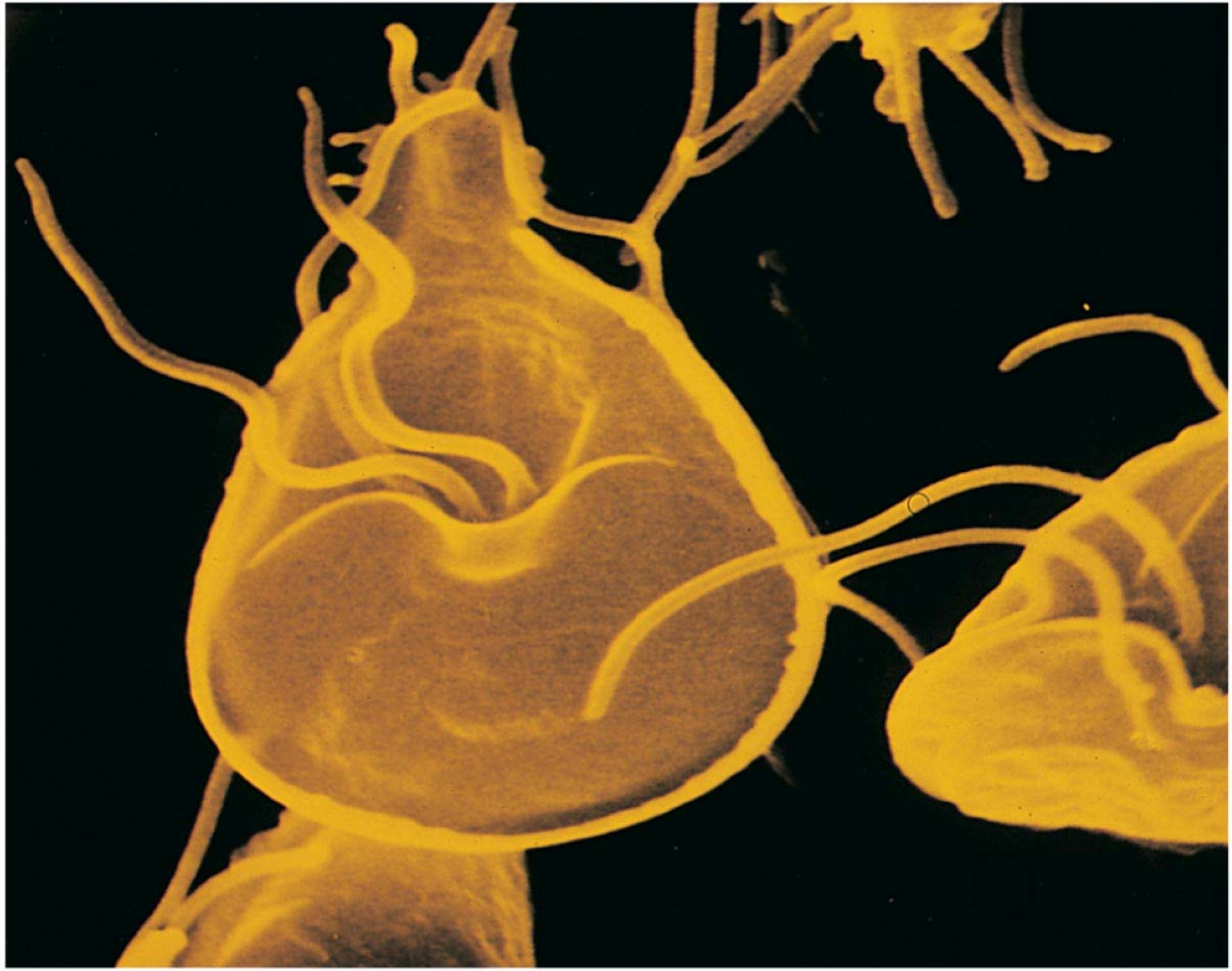
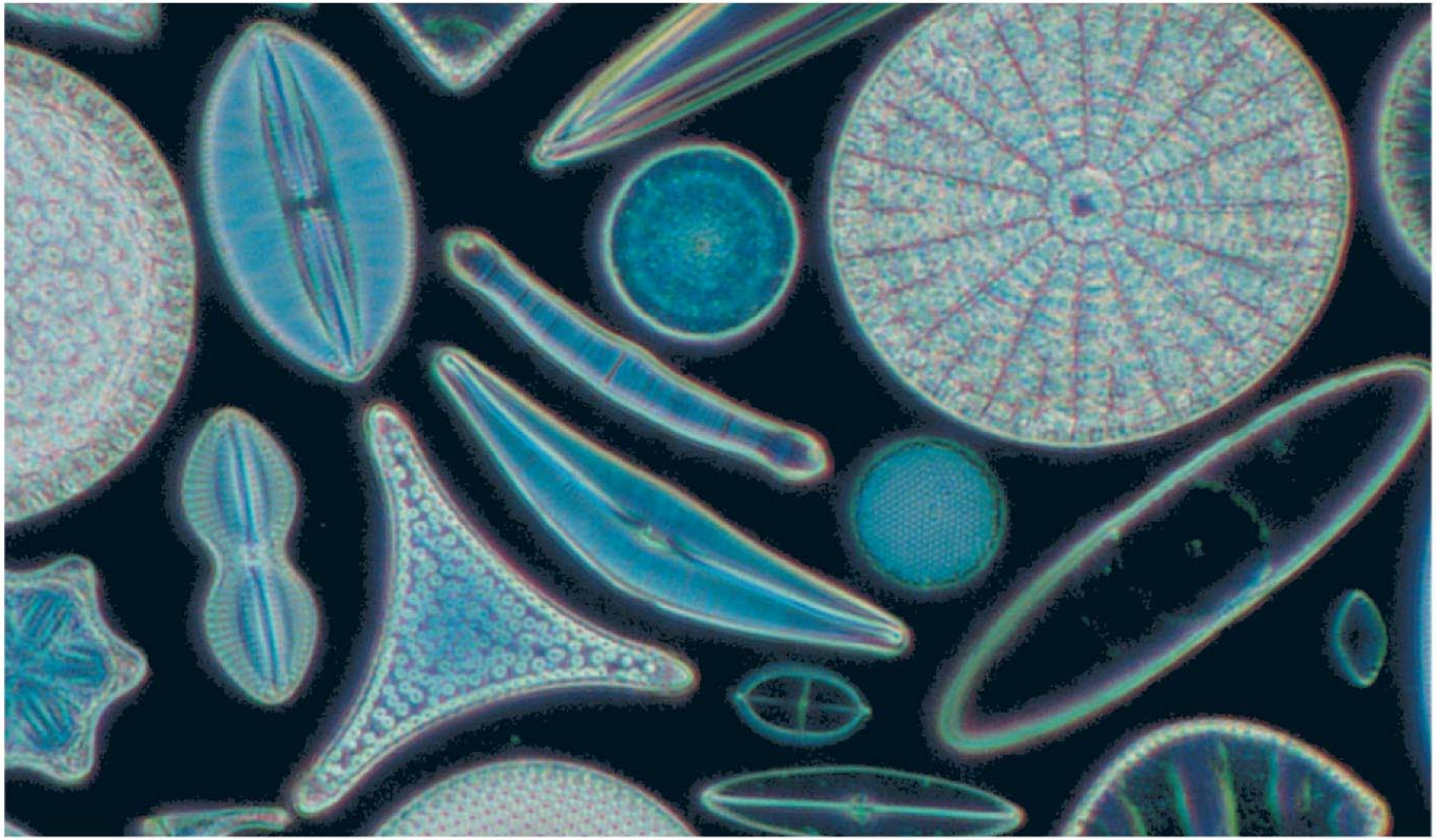


Fig. 28-03h



50 µm

Fig. 28-03i

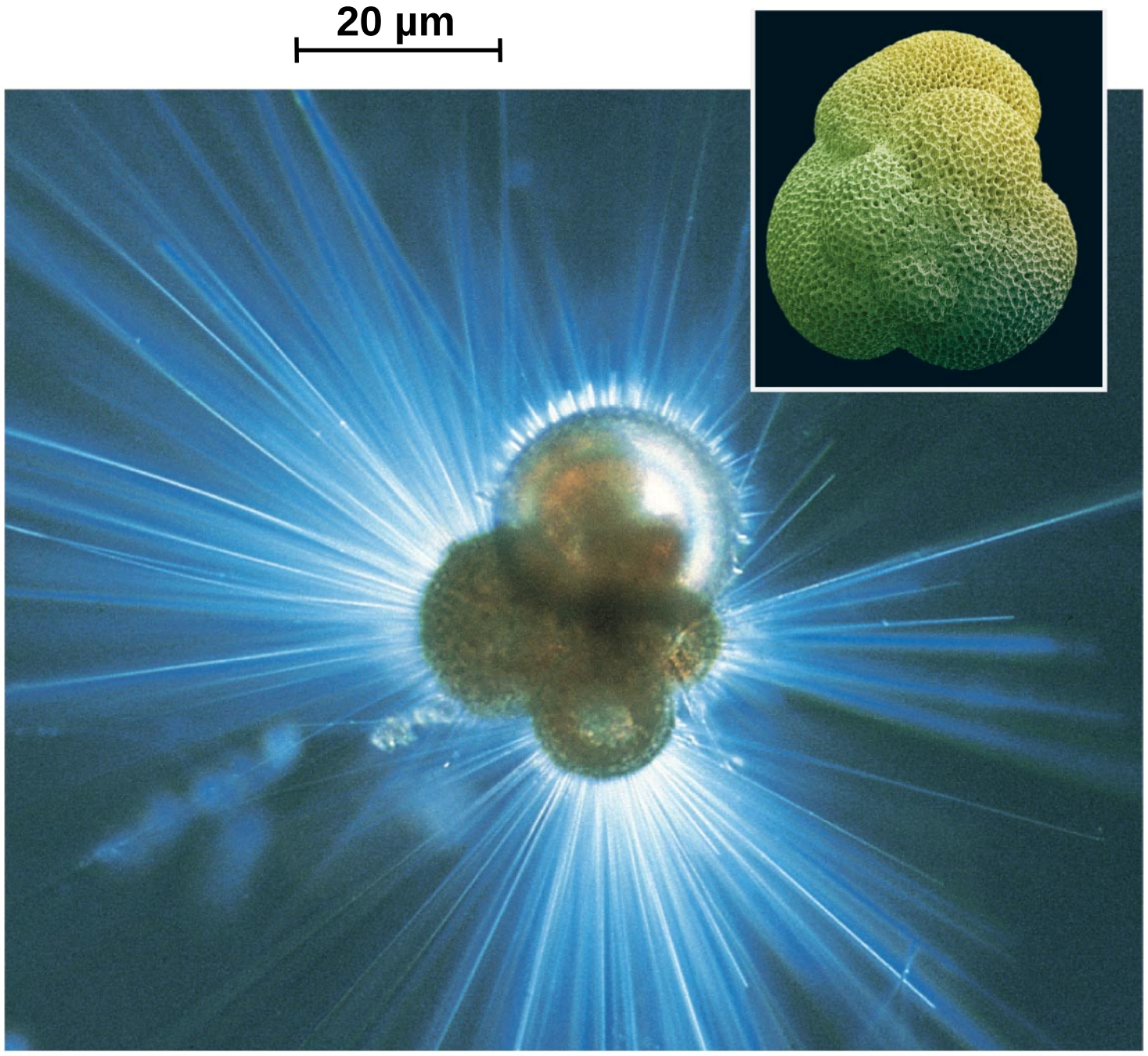


Fig. 28-03j

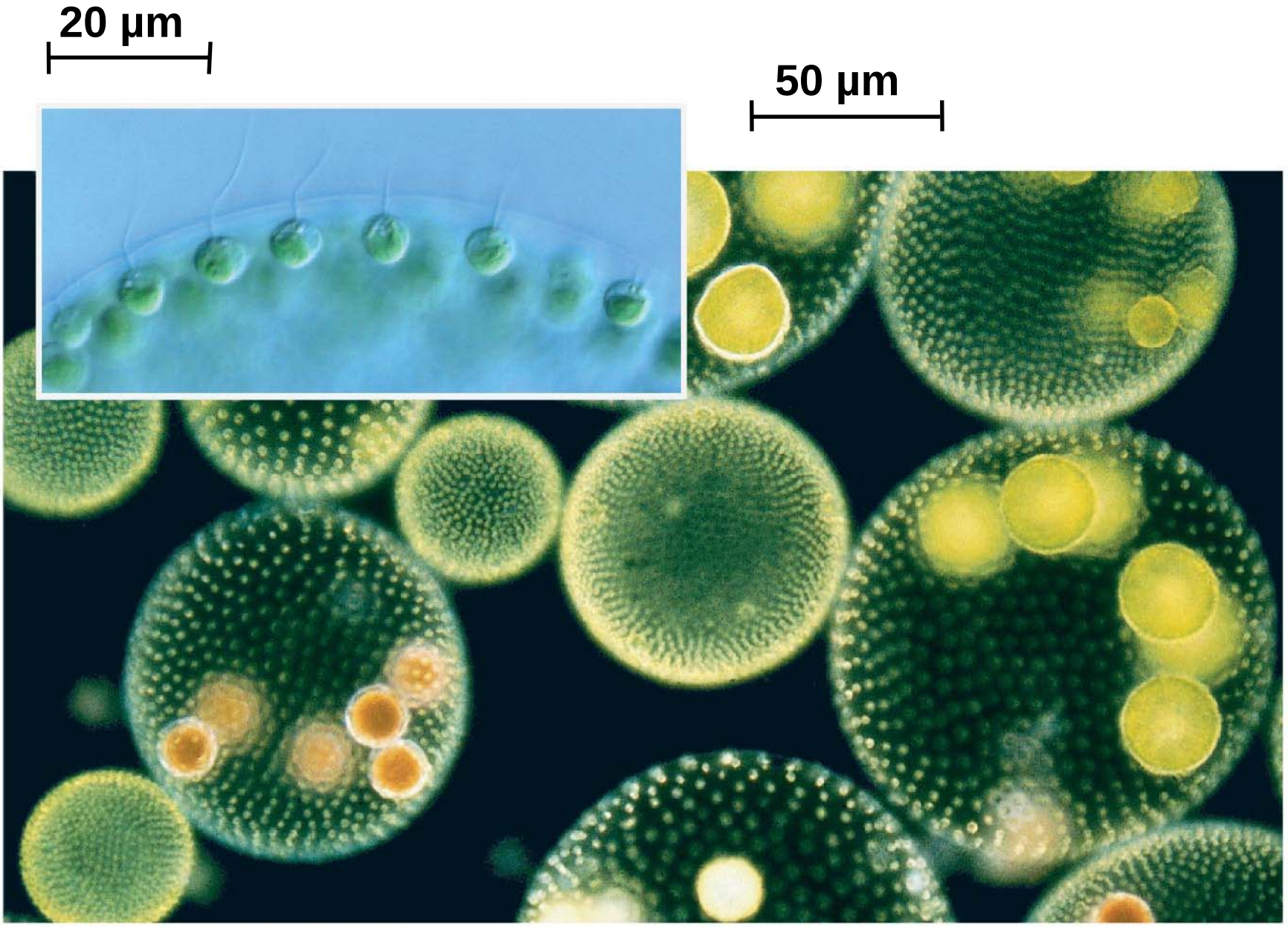
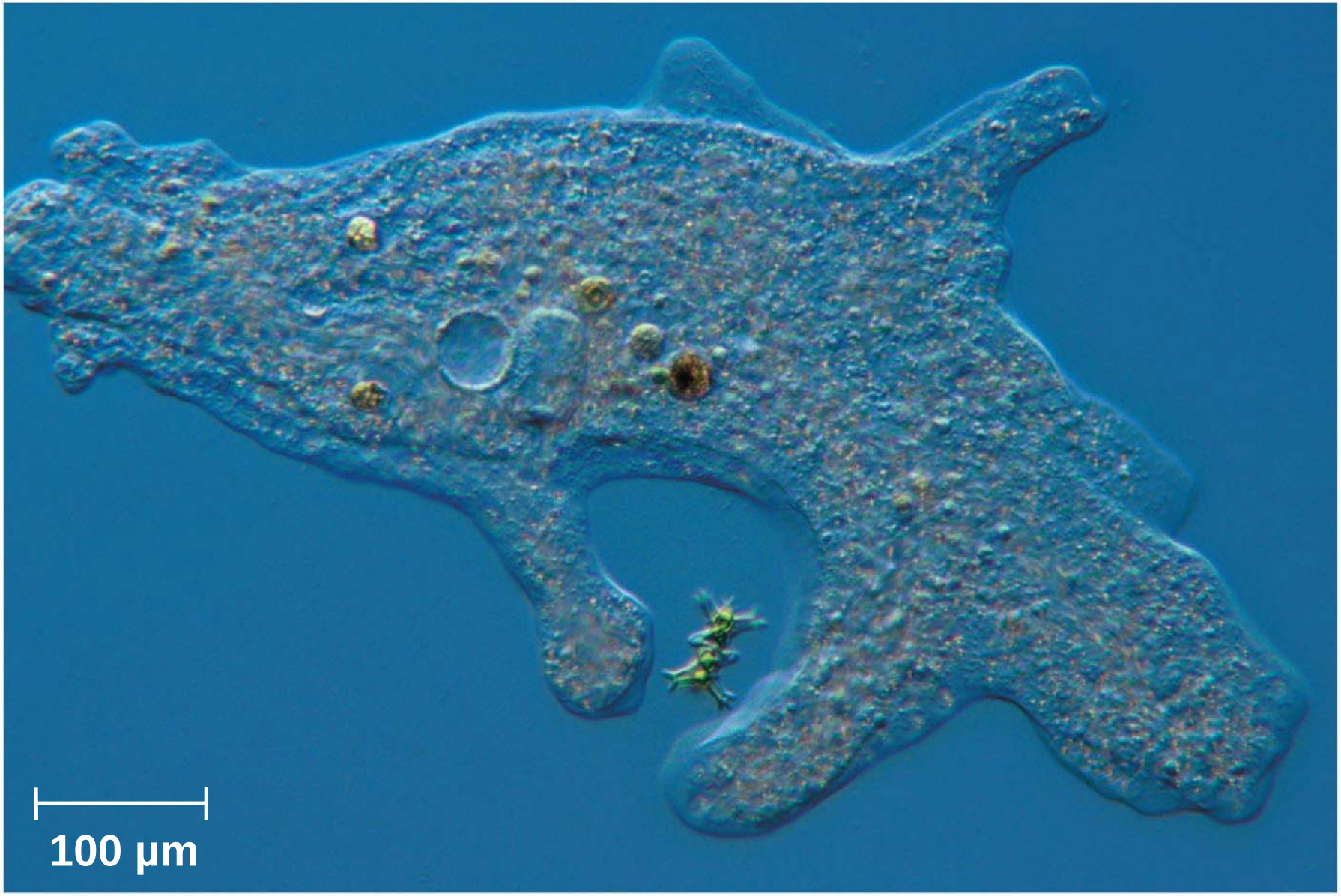


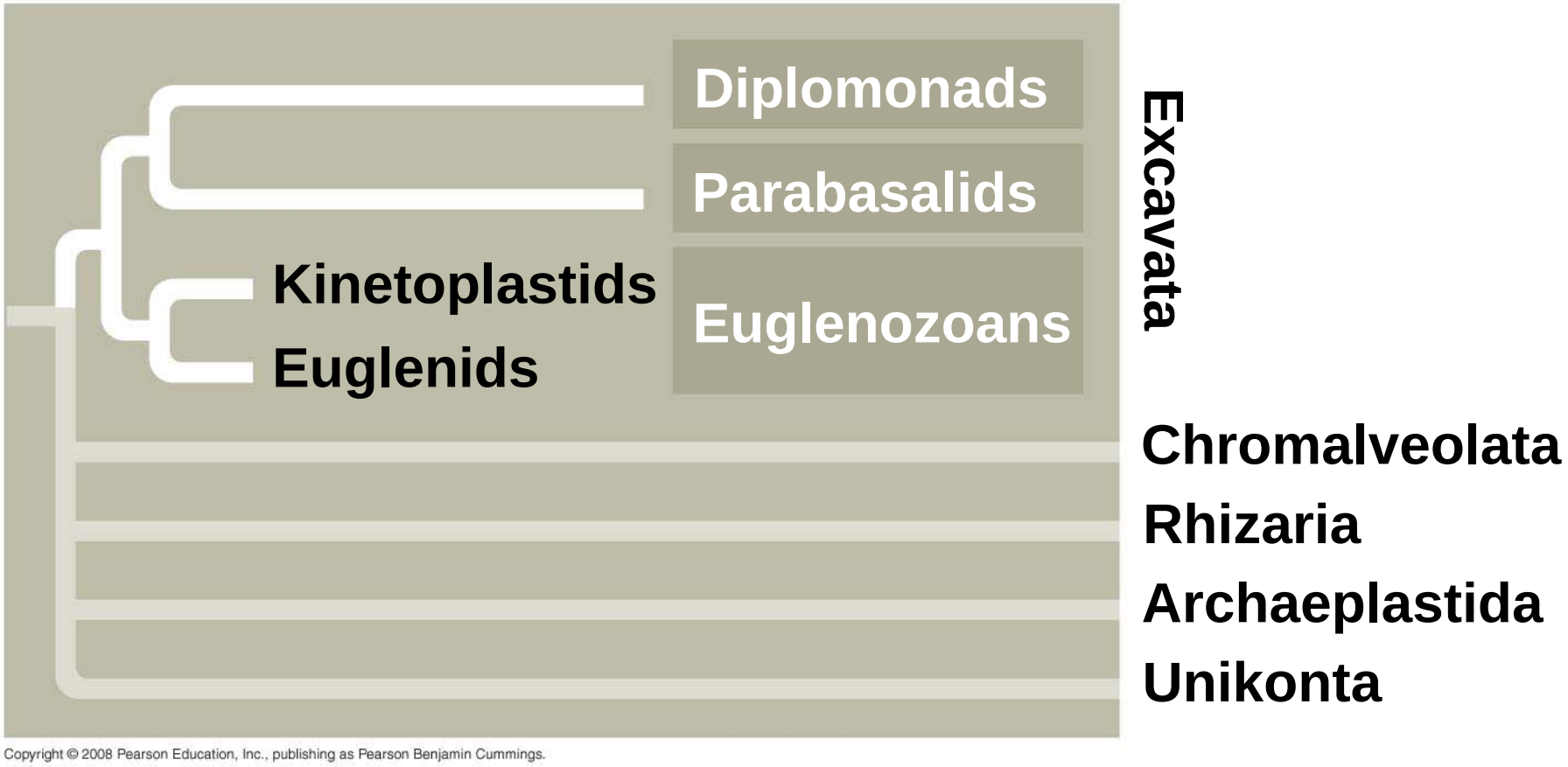
Fig. 28-03l



Concept 28.2: Excavates include protists with modified mitochondria and protists with unique flagella

- The clade **Excavata** is characterized by its cytoskeleton
- Some members have a feeding groove
- This controversial group includes the diplomonads, parabasalids, and euglenozoans

Fig. 28-UN1

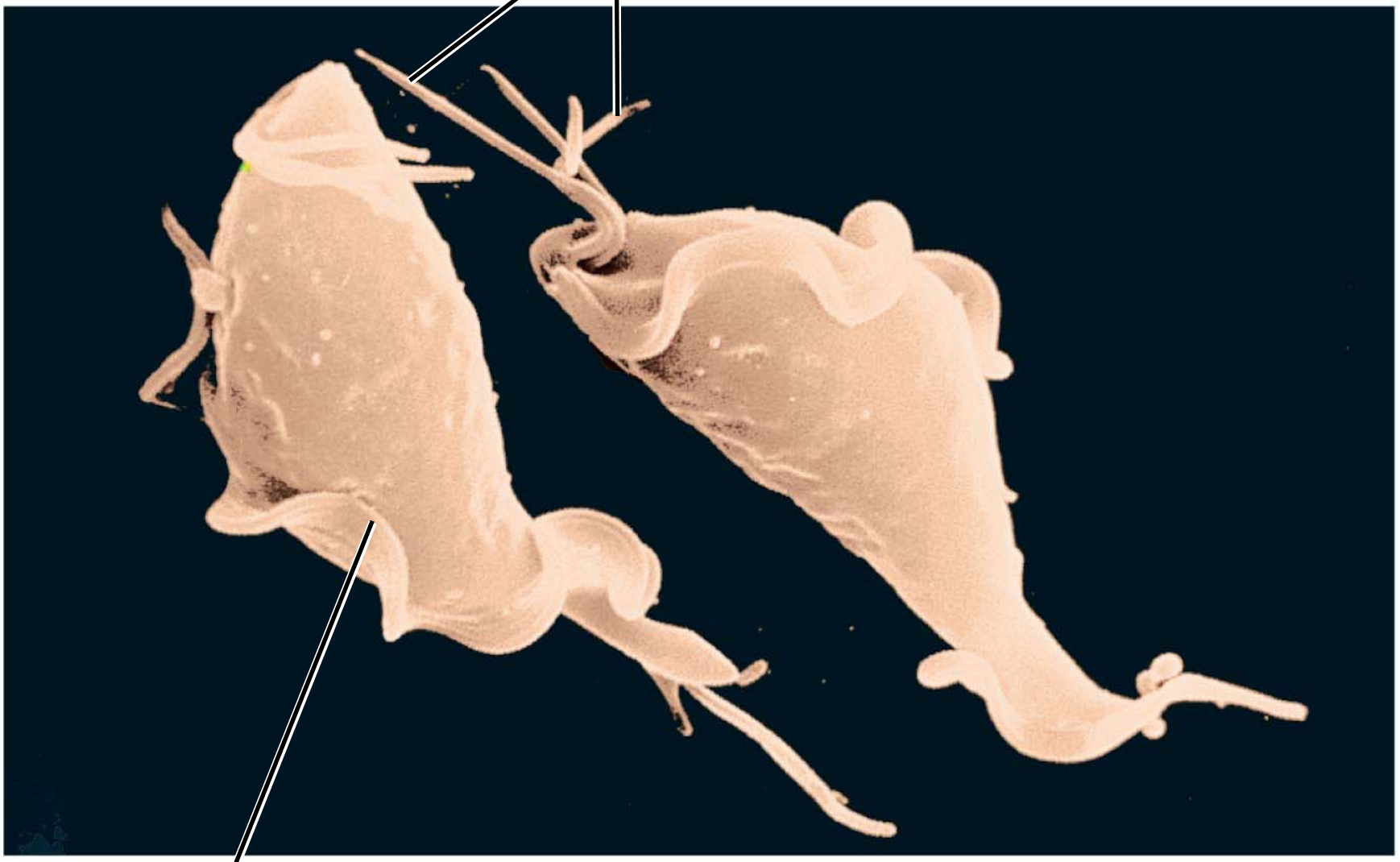


Diplomonads and Parabasalids

- 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

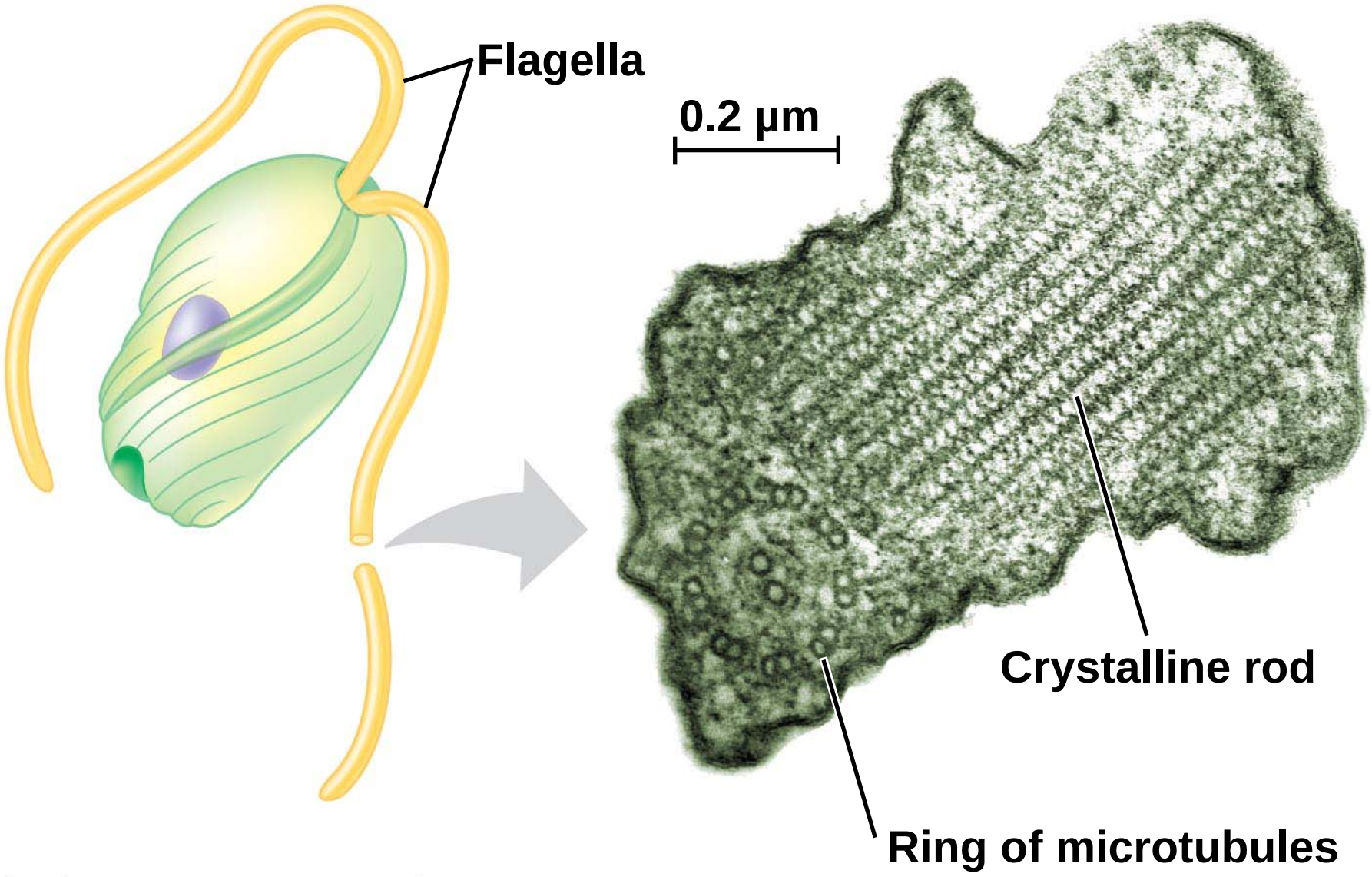
Fig. 28-04



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

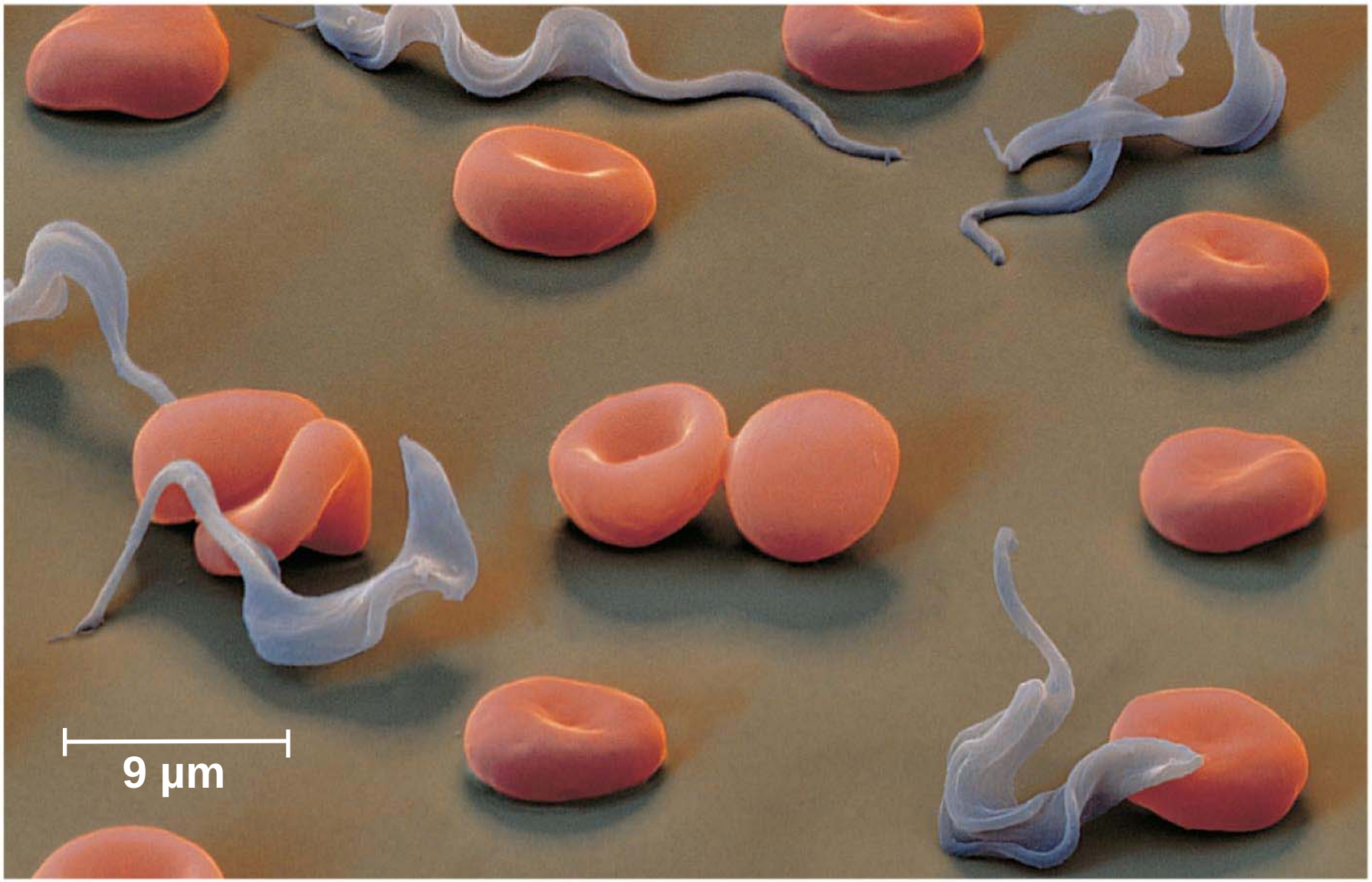
Fig. 28-05



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

Fig. 28-06



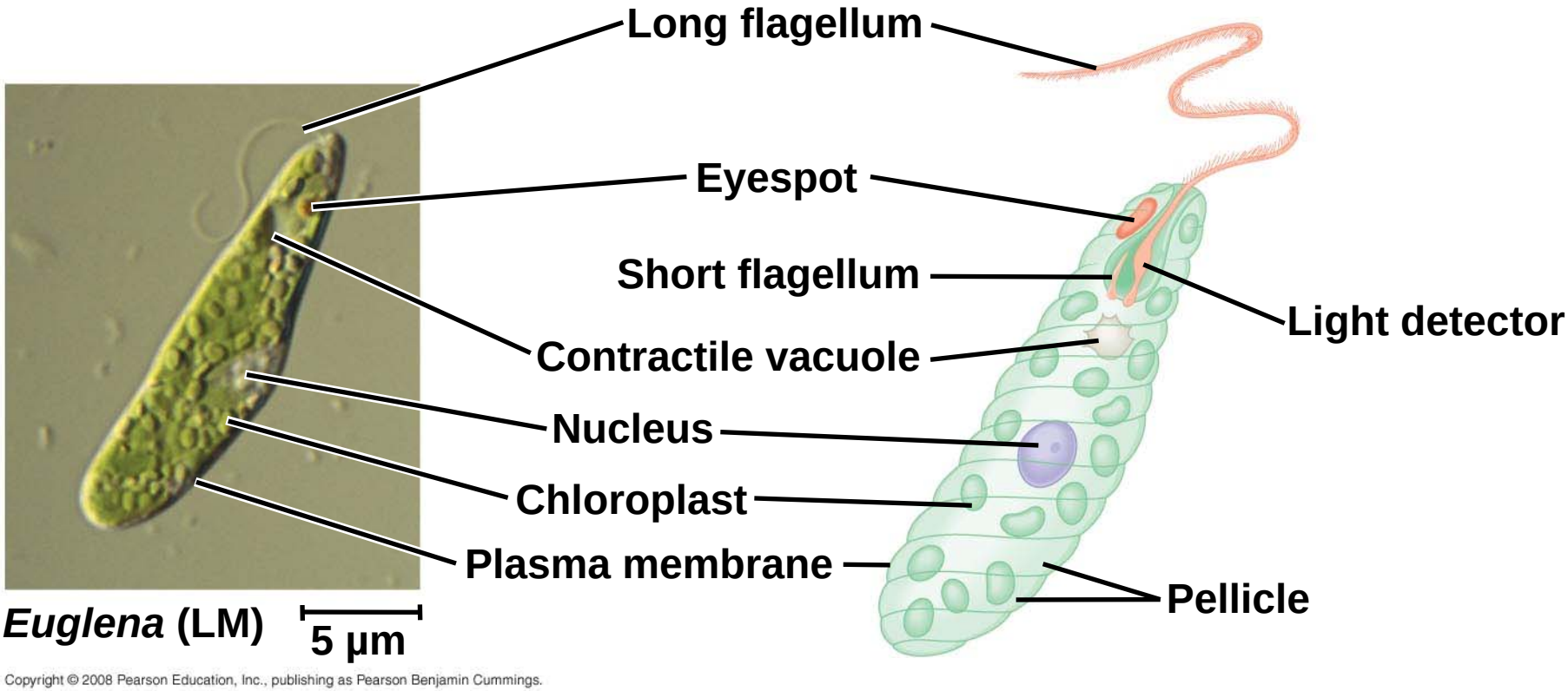
Euglenids

- **Euglenids** have one or two flagella that emerge from a pocket at one end of the cell
- Some species can be both autotrophic and heterotrophic

PLAY Video: *Euglena*

PLAY Video: *Euglena* Motion

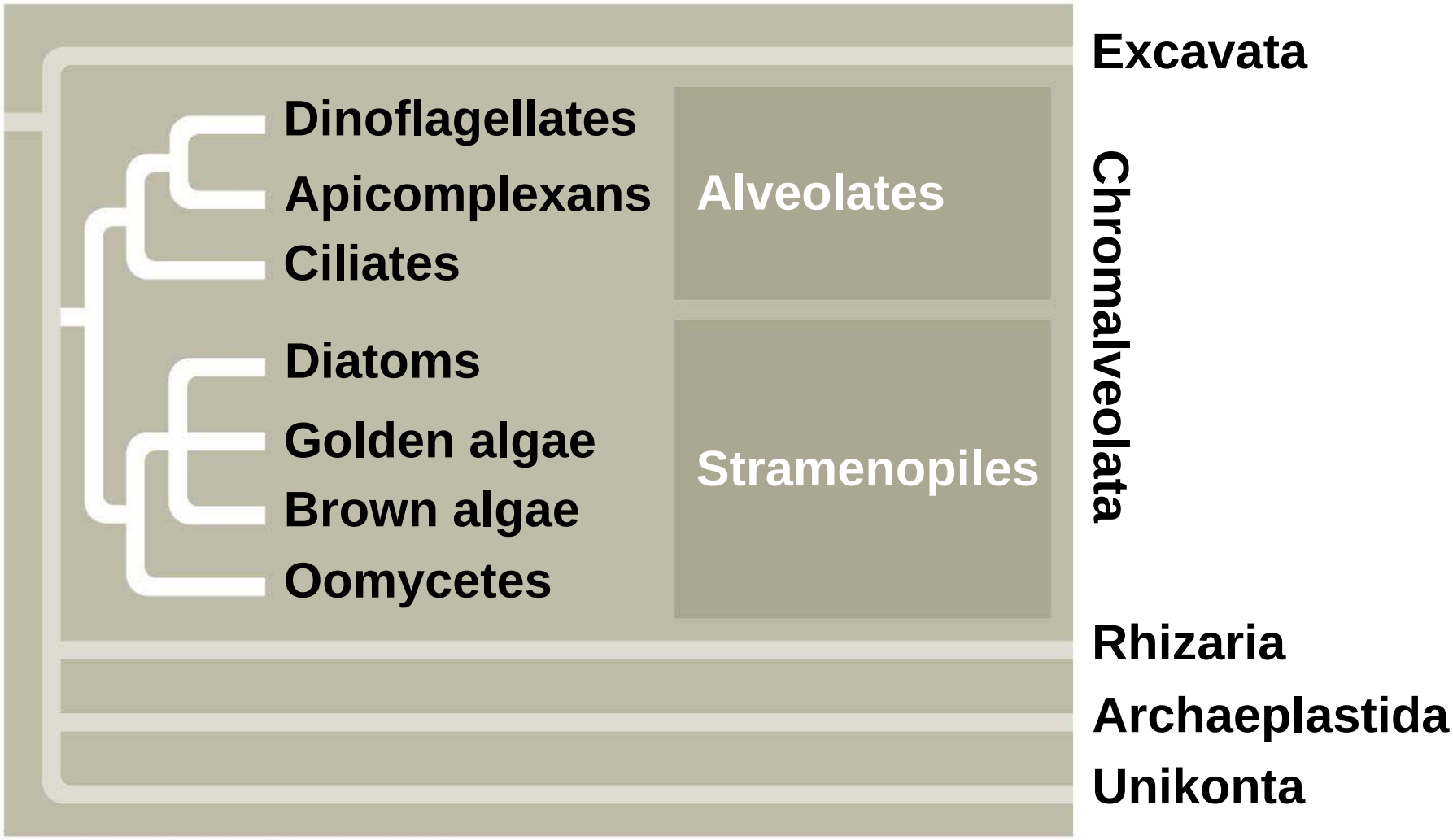
Fig. 28-07



Concept 28.3: Chromalveolates may have originated by secondary endosymbiosis

- Some data suggest that the clade **Chromalveolata** is monophyletic and originated by a secondary endosymbiosis event
- The proposed endosymbiont is a red alga
- This clade is controversial and includes the alveolates and the stramenopiles

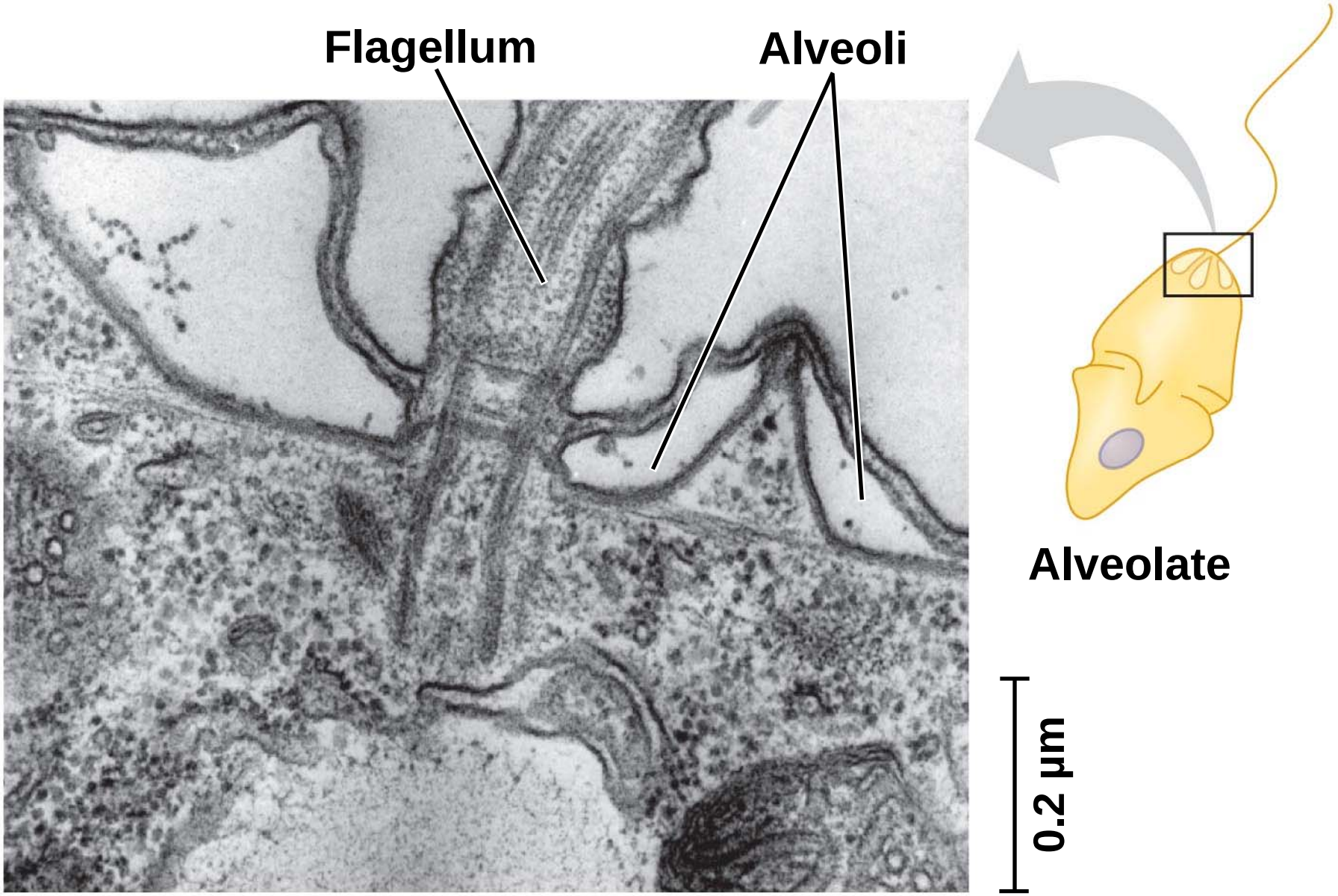
Fig. 28-UN2



Alveolates

- Members of the clade **Alveolata** have membrane-bounded sacs (alveoli) just under the plasma membrane
- The function of the alveoli is unknown
- Alveolata includes the dinoflagellates, apicomplexans, and ciliates

Fig. 28-08



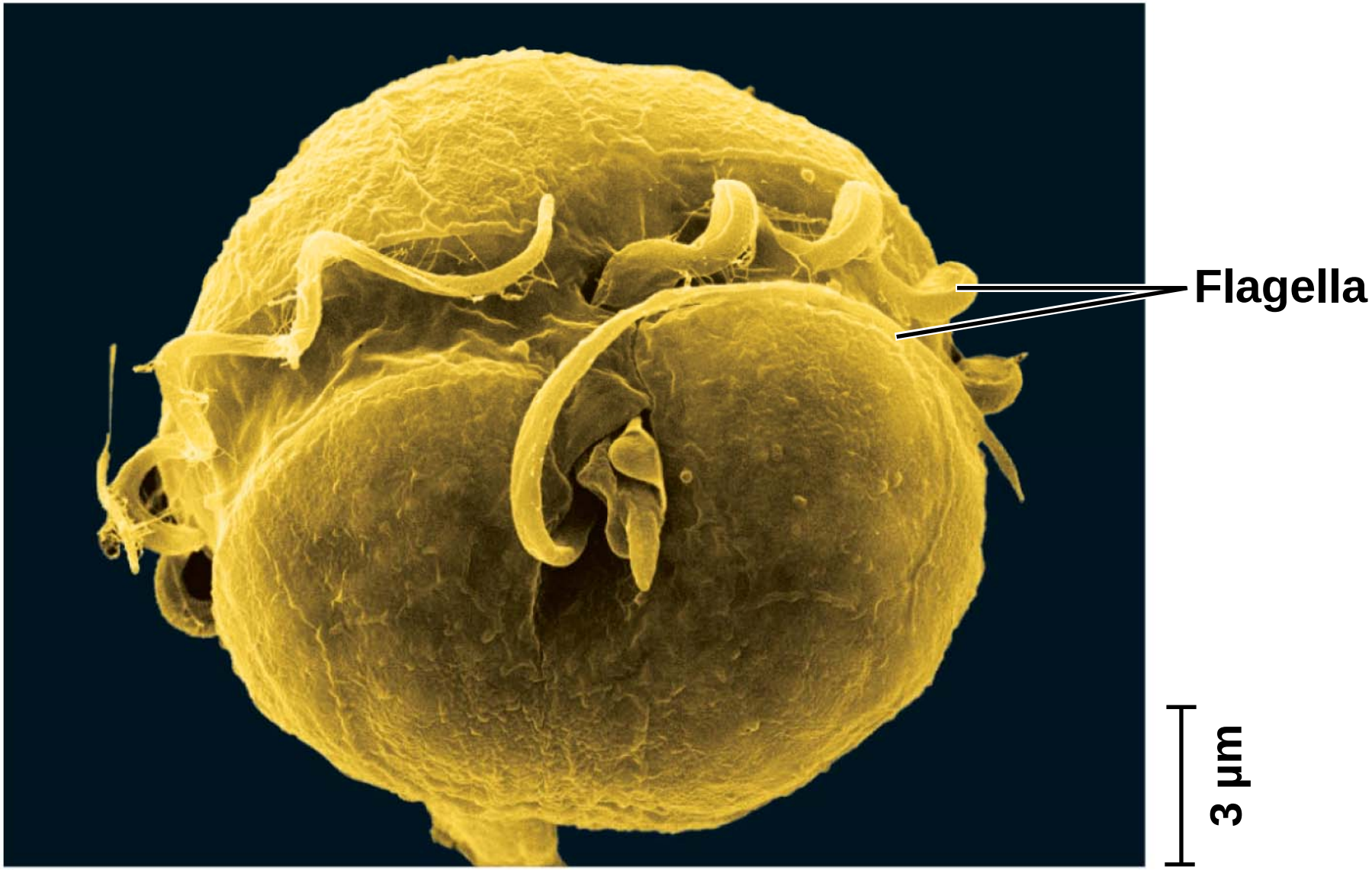
Dinoflagellates

- **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”

Fig. 28-09



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

Fig. 28-10-1

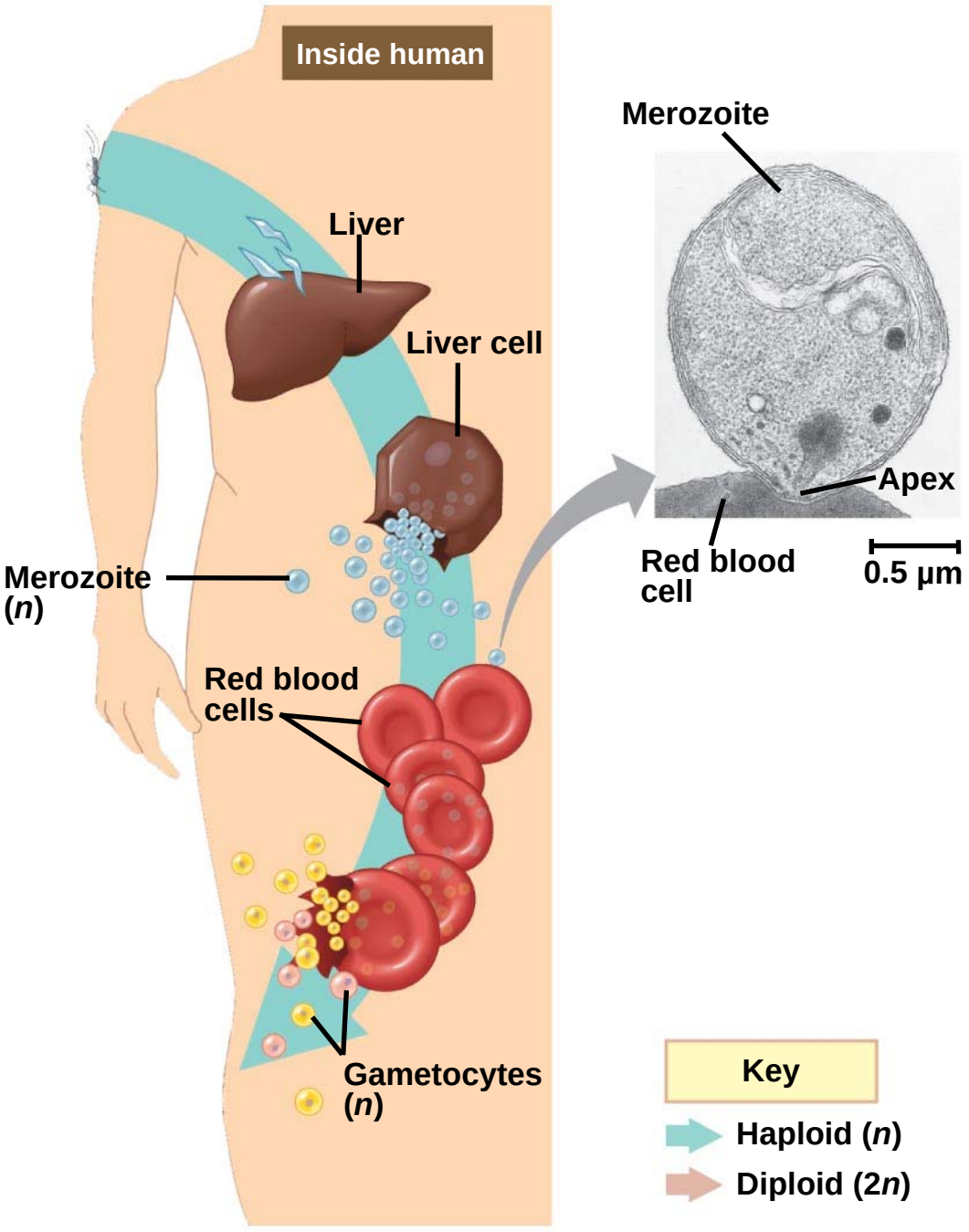


Fig. 28-10-2

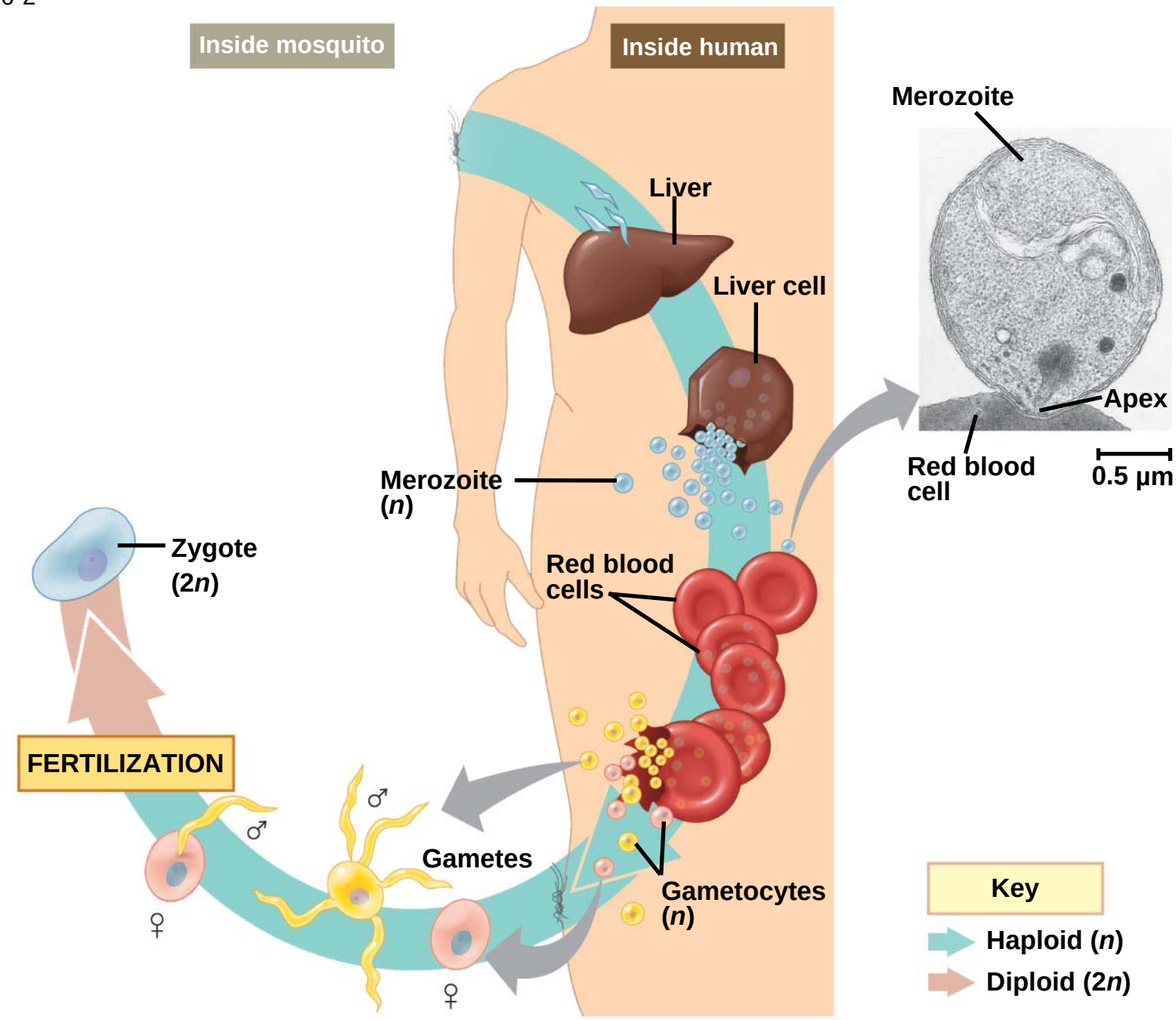
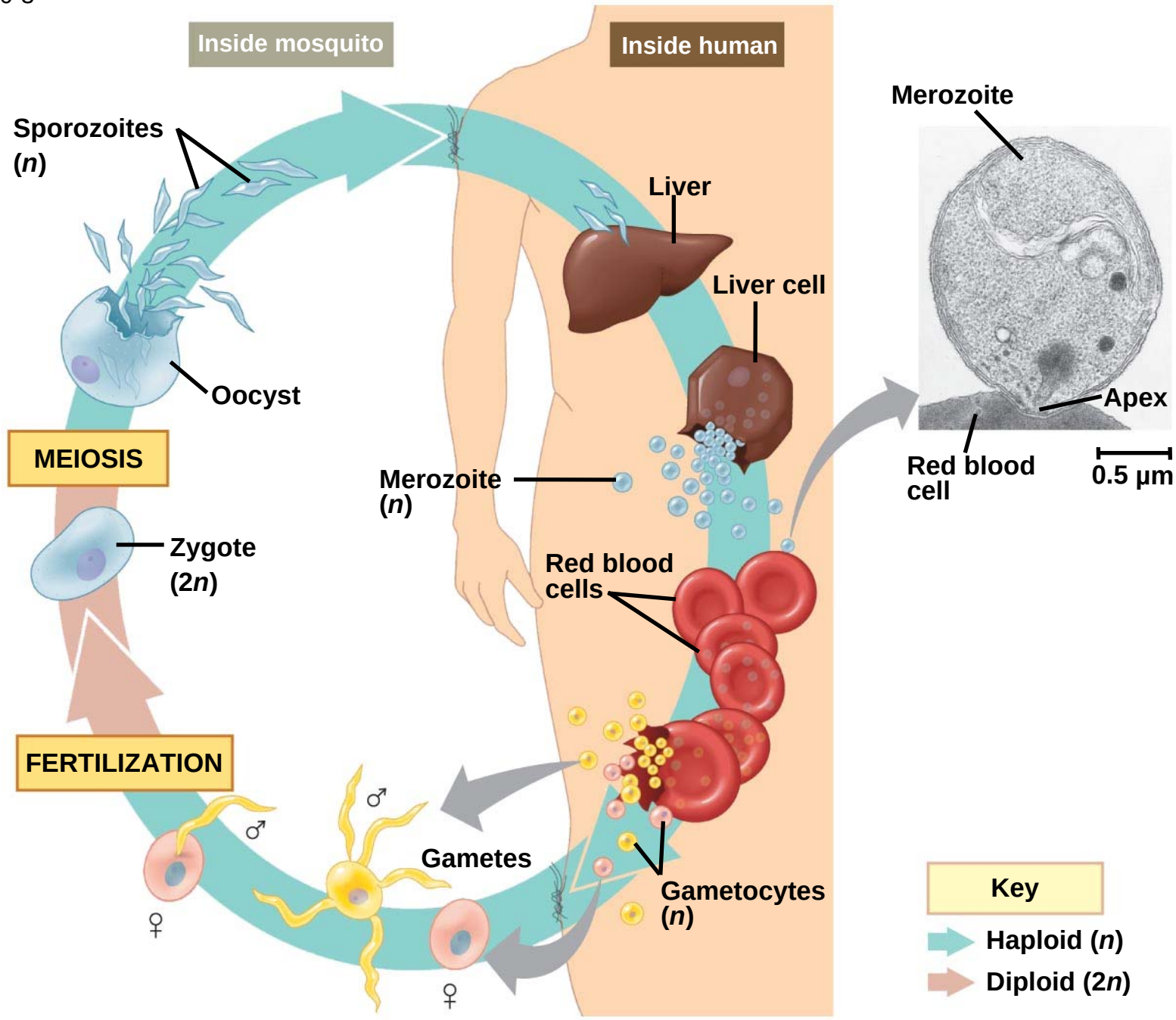


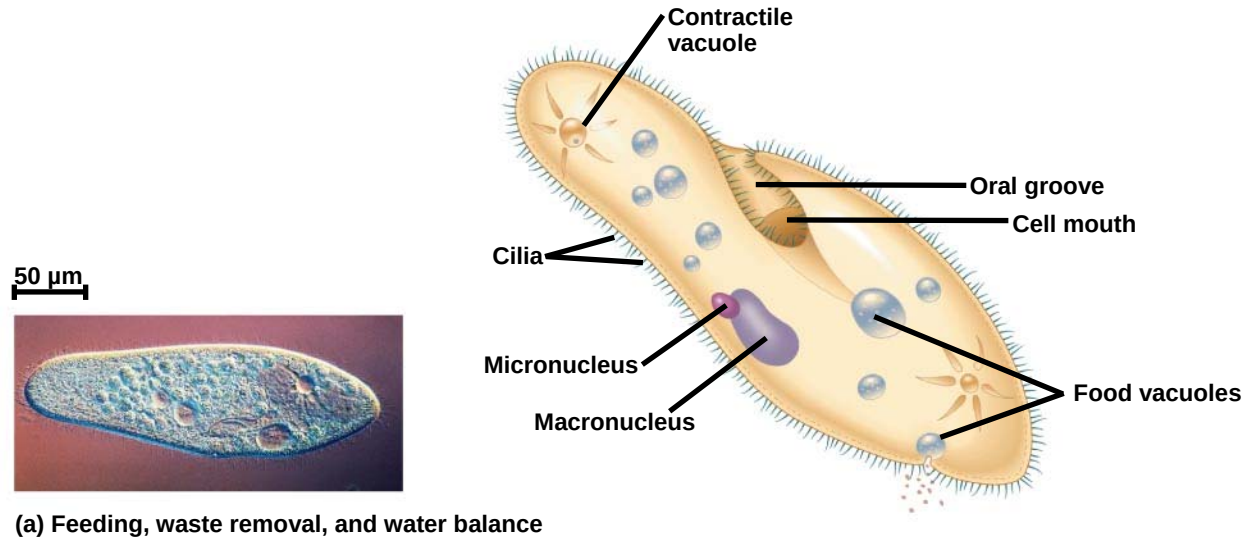
Fig. 28-10-3



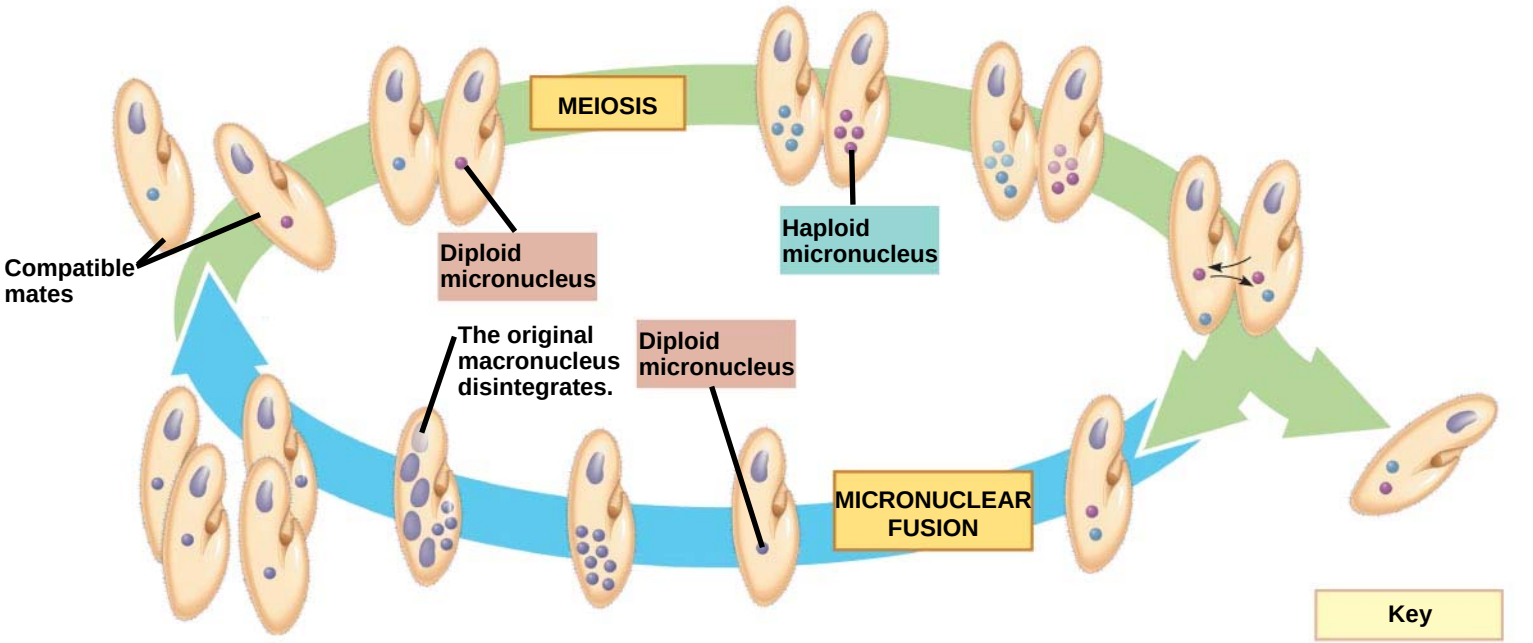
Ciliates

- **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 binary fission

Fig. 28-11

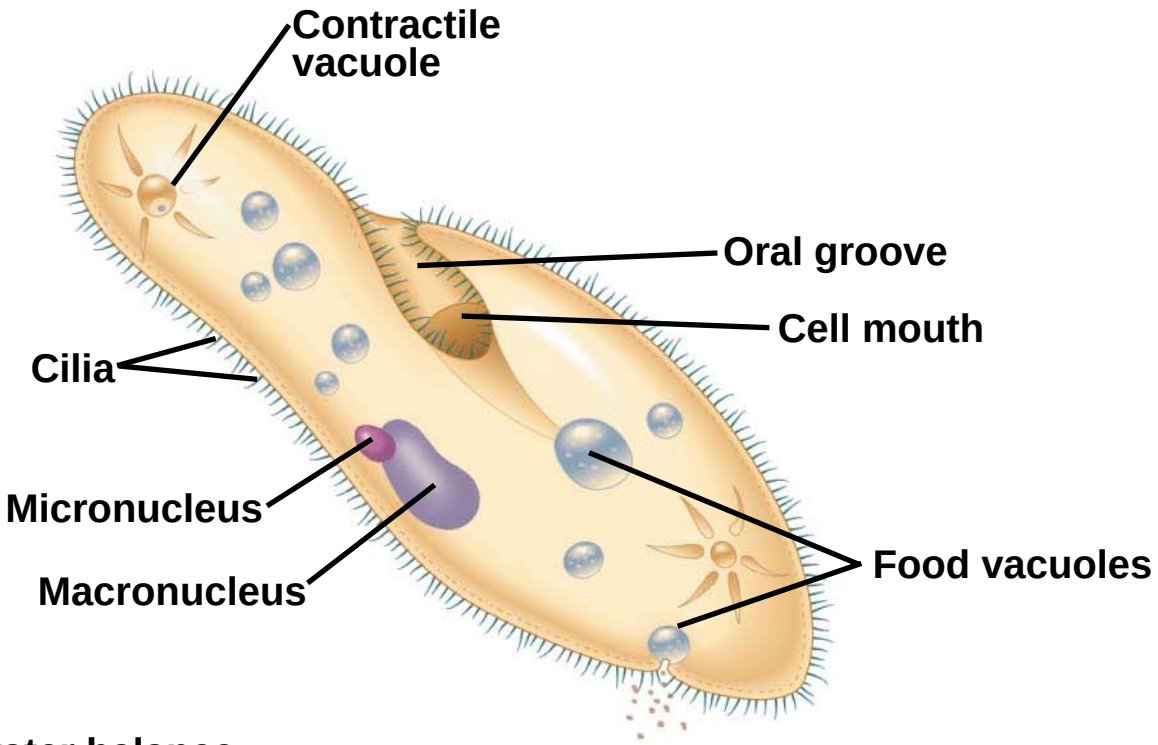


(a) Feeding, waste removal, and water balance



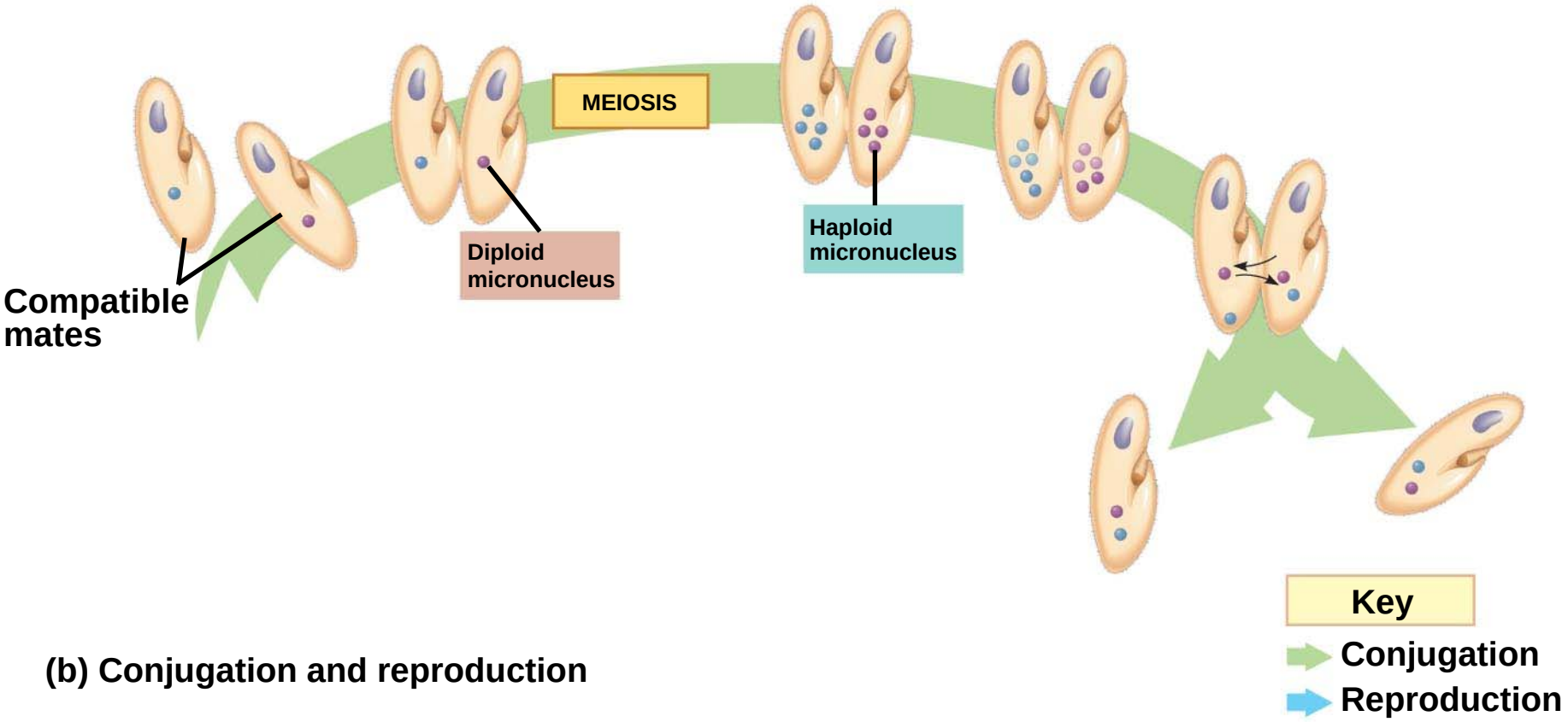
(b) Conjugation and reproduction

Fig. 28-11a



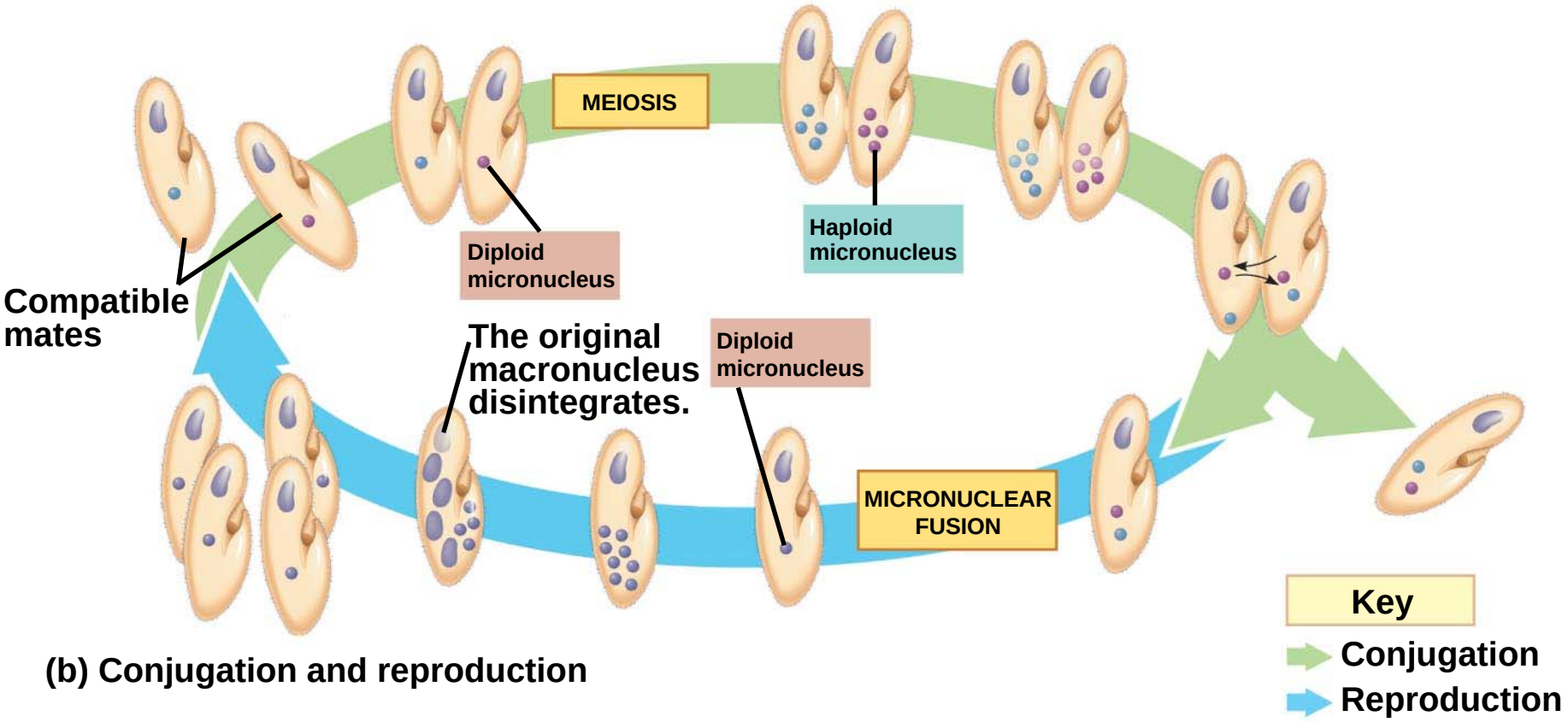
(a) Feeding, waste removal, and water balance

Fig. 28-11b-1



(b) Conjugation and reproduction

Fig. 28-11b-2



(b) Conjugation and reproduction

PLAY Video: *Paramecium* Cilia

PLAY Video: *Paramecium* Vacuole

PLAY Video: *Vorticella* Cilia

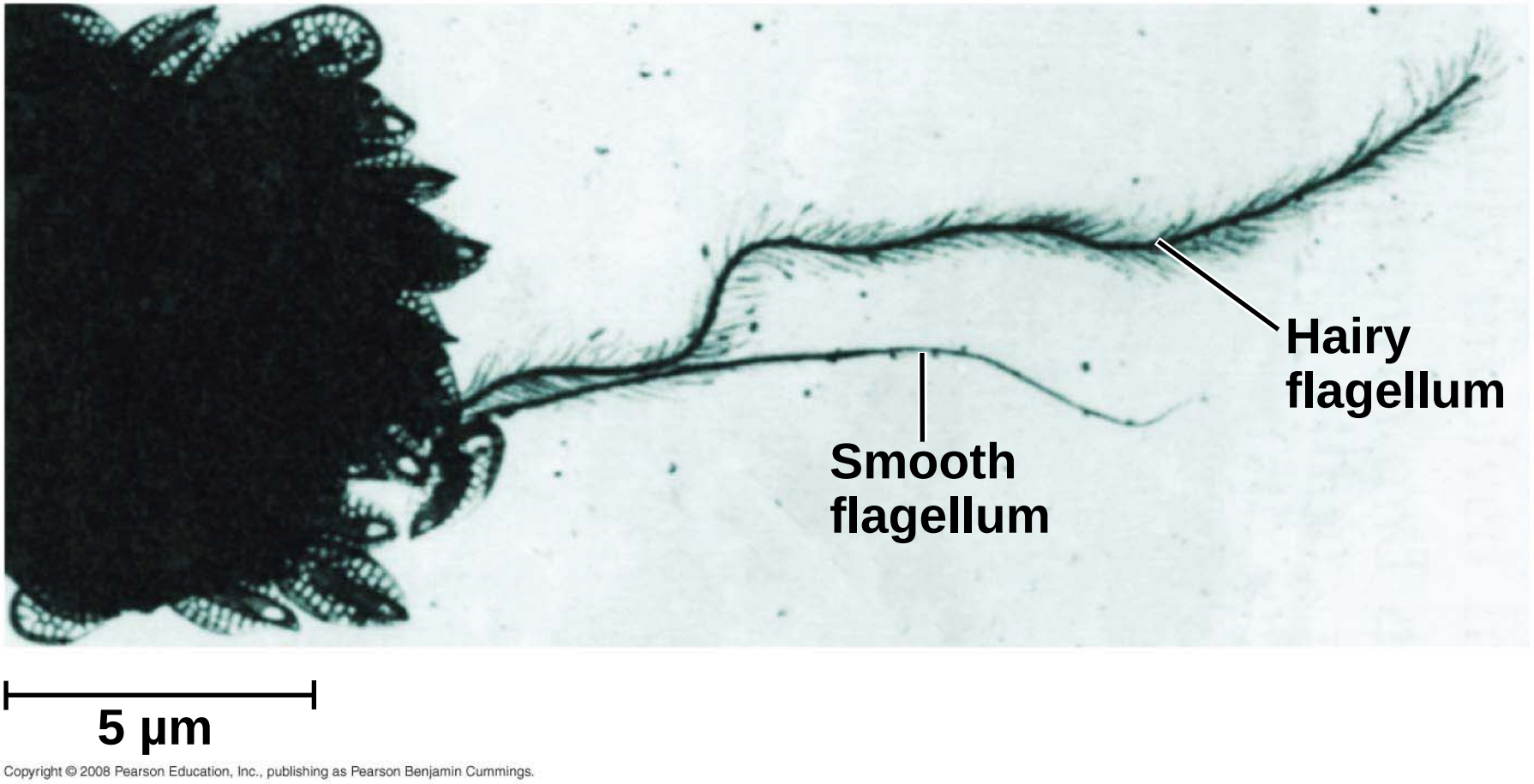
PLAY Video: *Vorticella* Detail

PLAY Video: *Vorticella* Habitat

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

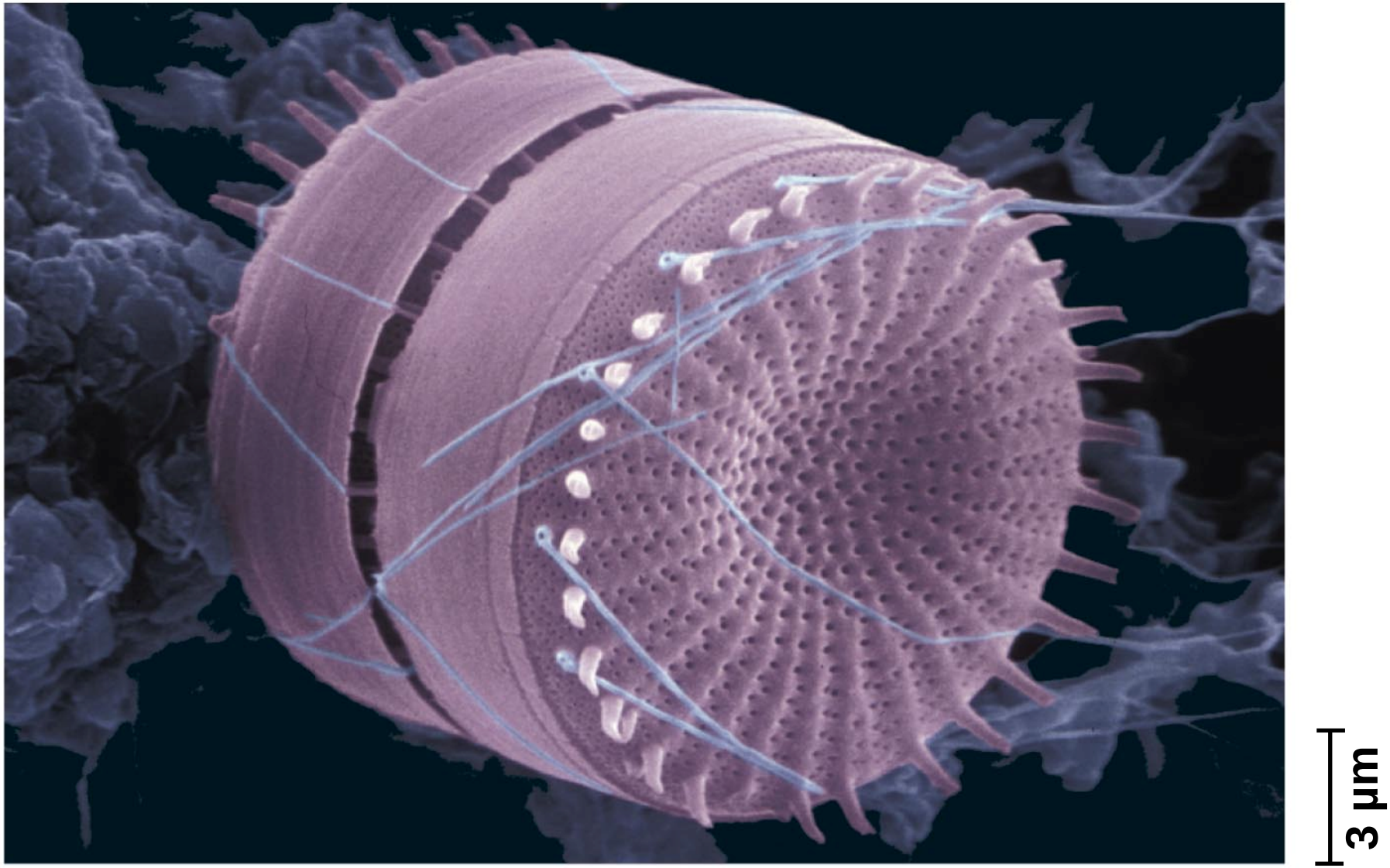
Fig. 28-12



Diatoms

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

Fig. 28-13



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

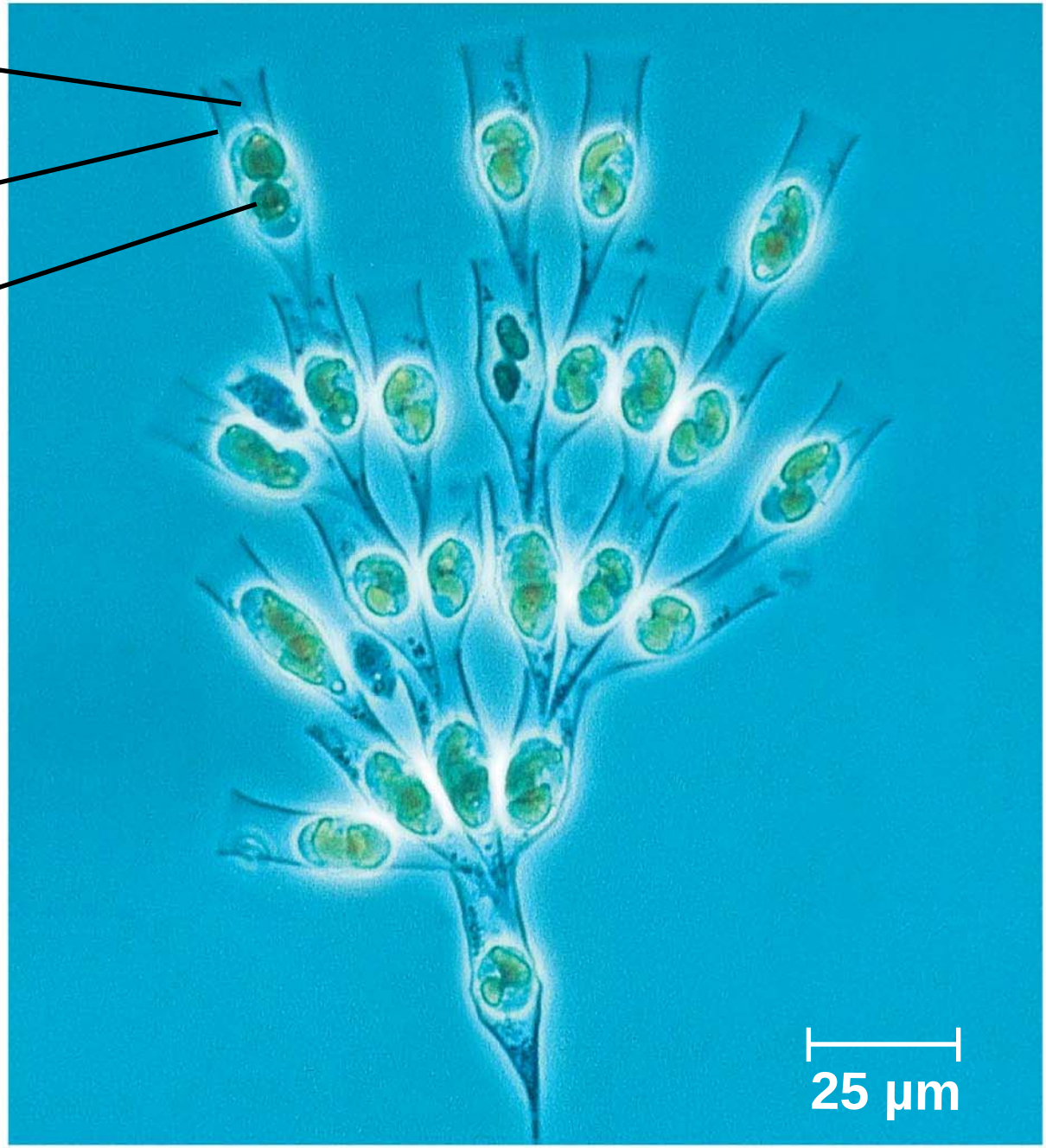
PLAY Video: Diatoms Moving

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

Fig. 28-14

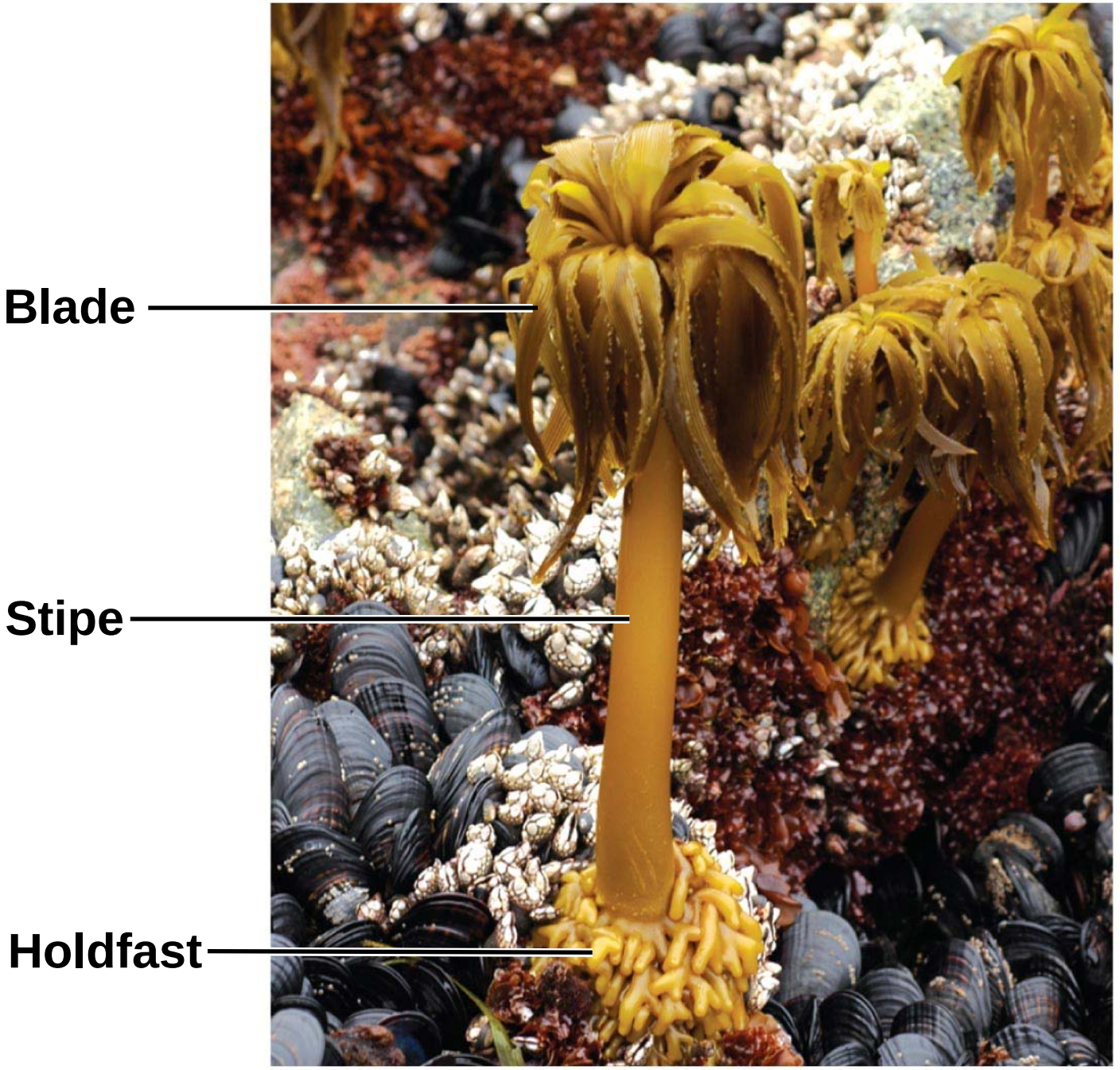


Brown Algae

- **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**

Fig. 28-15



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

Fig. 28-16-1

10 cm

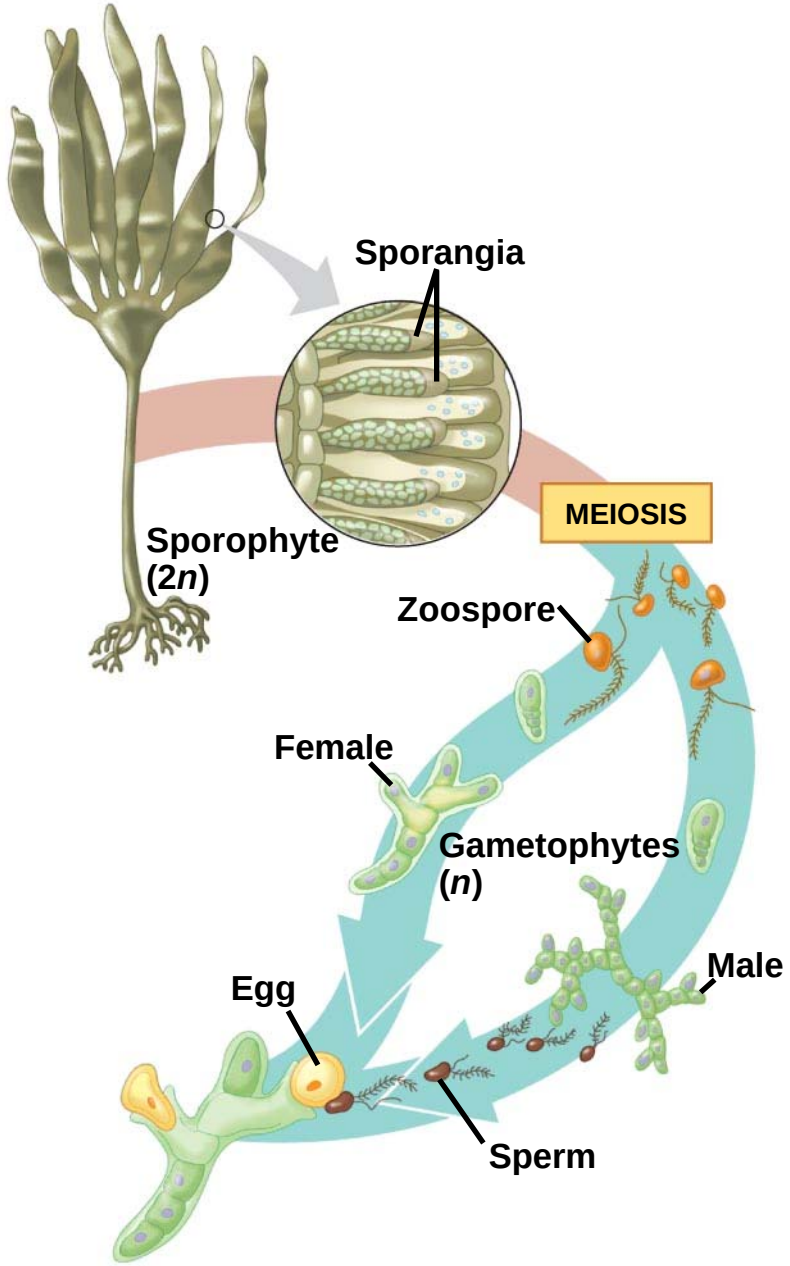
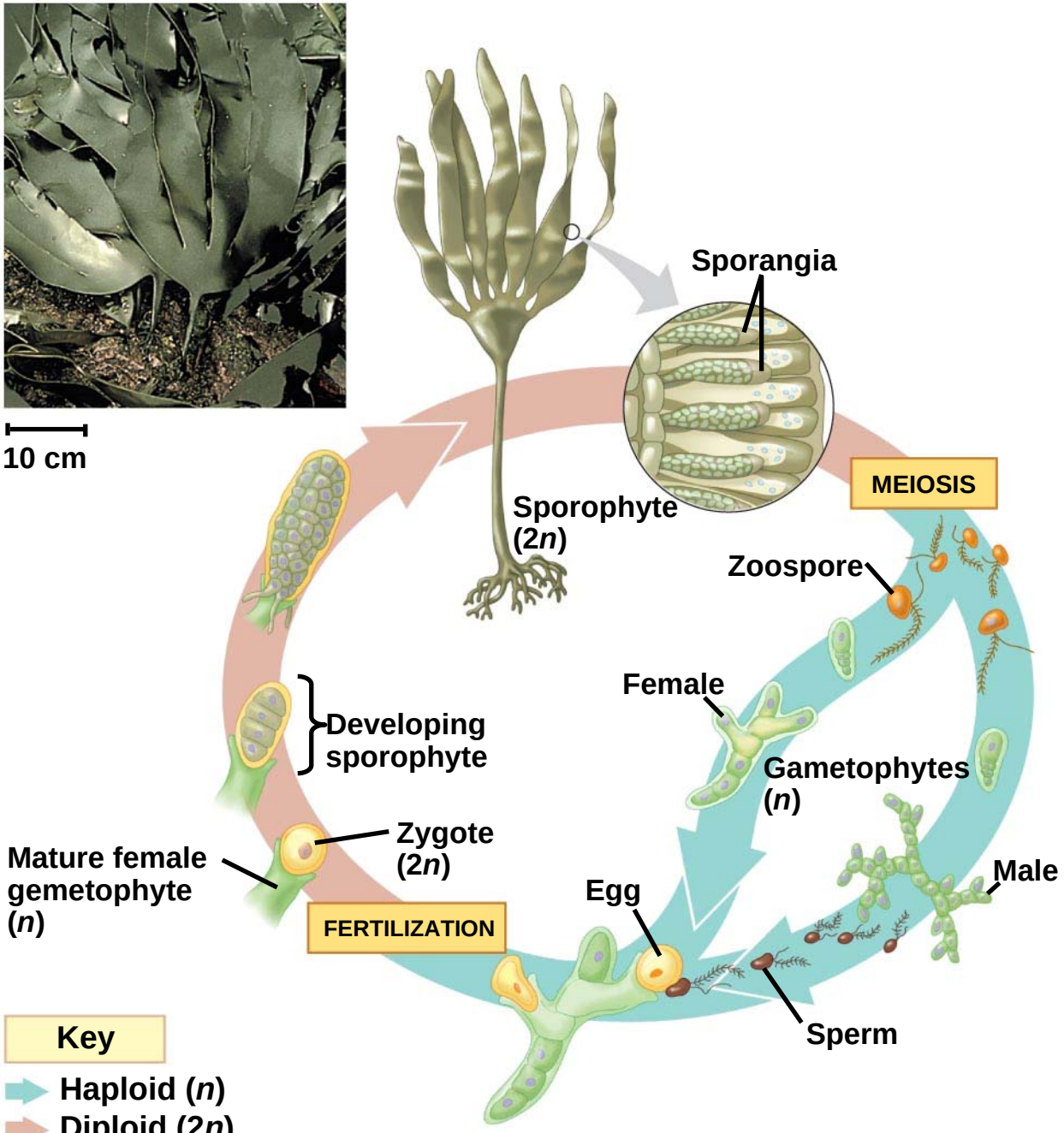


Fig. 28-16-2



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 blight

Fig. 28-17-1

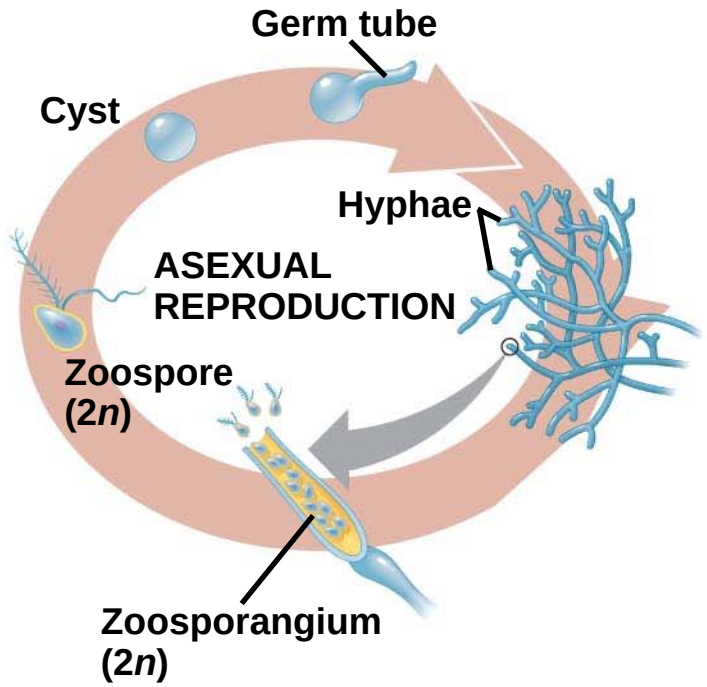


Fig. 28-17-2

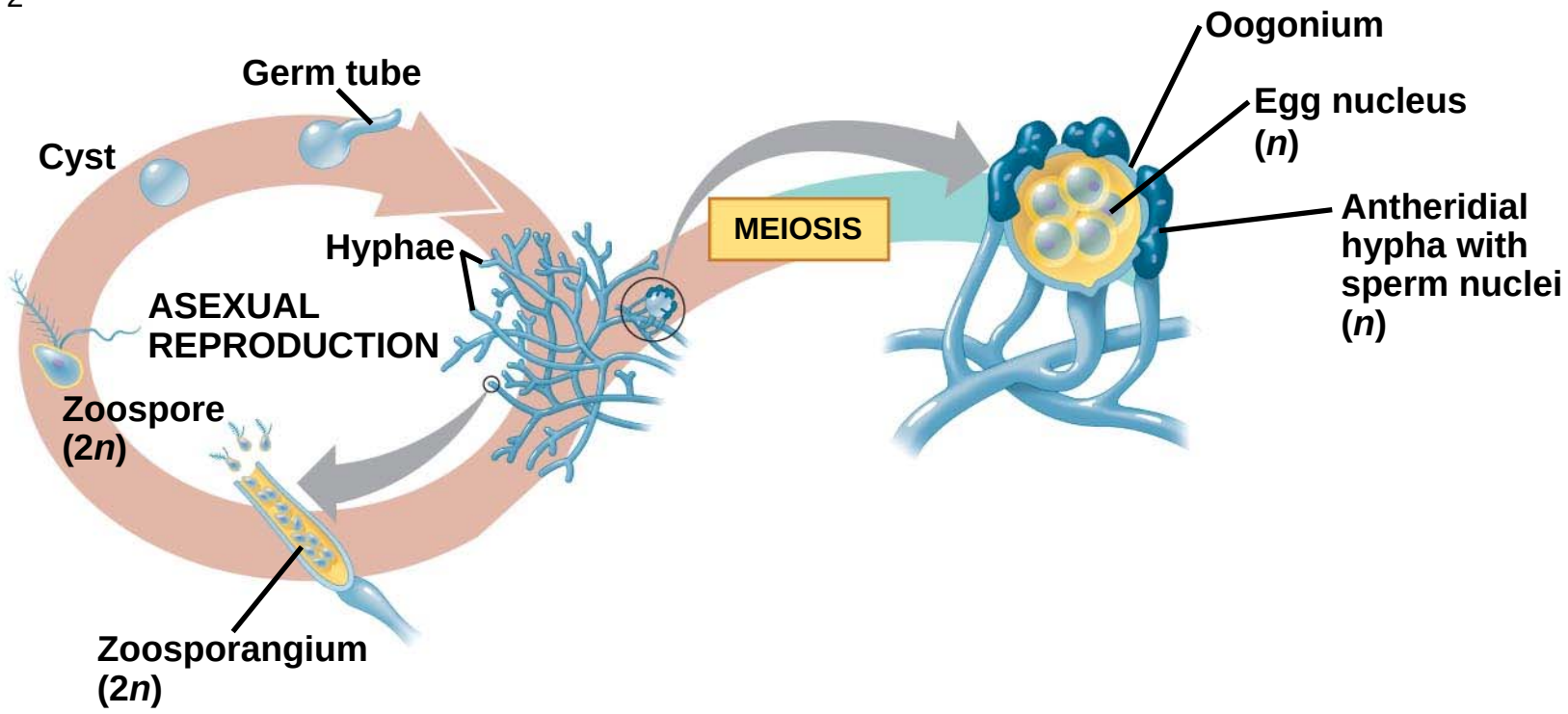
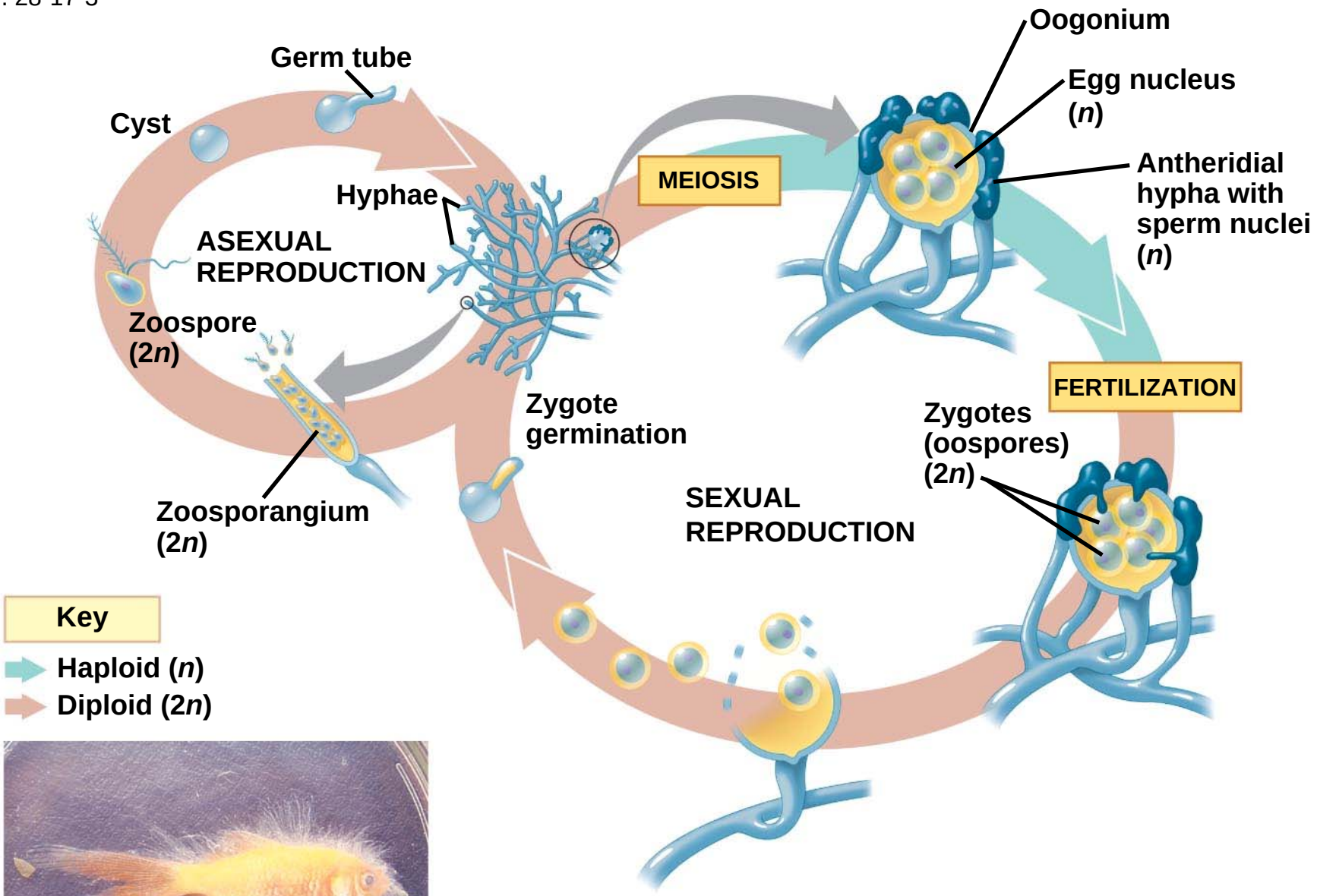


Fig. 28-17-3



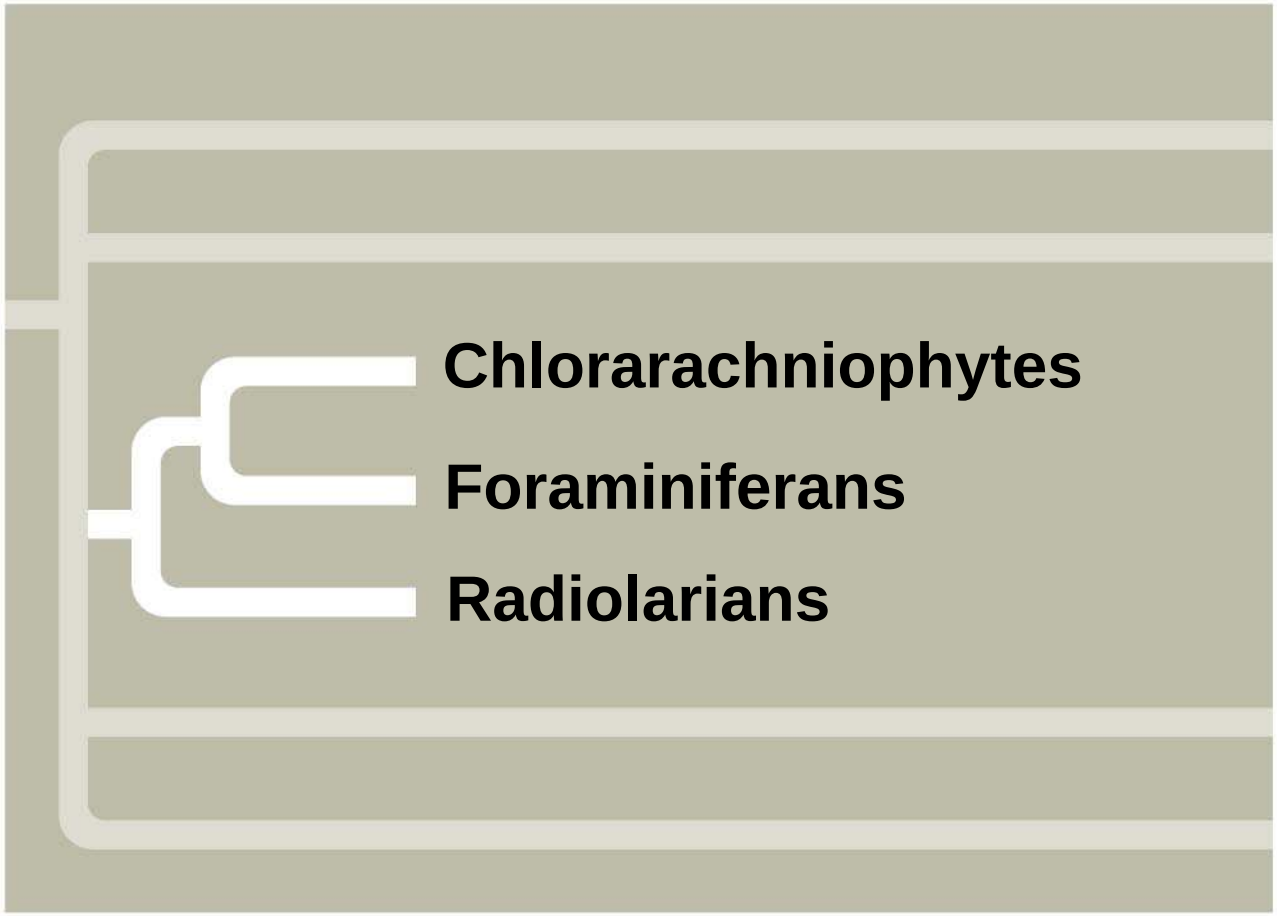
PLAY Video: Water Mold Oogonium

PLAY Video: Water Mold Zoospores

Concept 28.4: Rhizarians are a diverse group of protists defined by DNA similarities

- DNA evidence supports **Rhizaria** as a monophyletic clade
- Amoebas move and feed by **pseudopodia**; some but not all belong to the clade Rhizaria
- Rhizarians include forams and radiolarians

Fig. 28-UN3



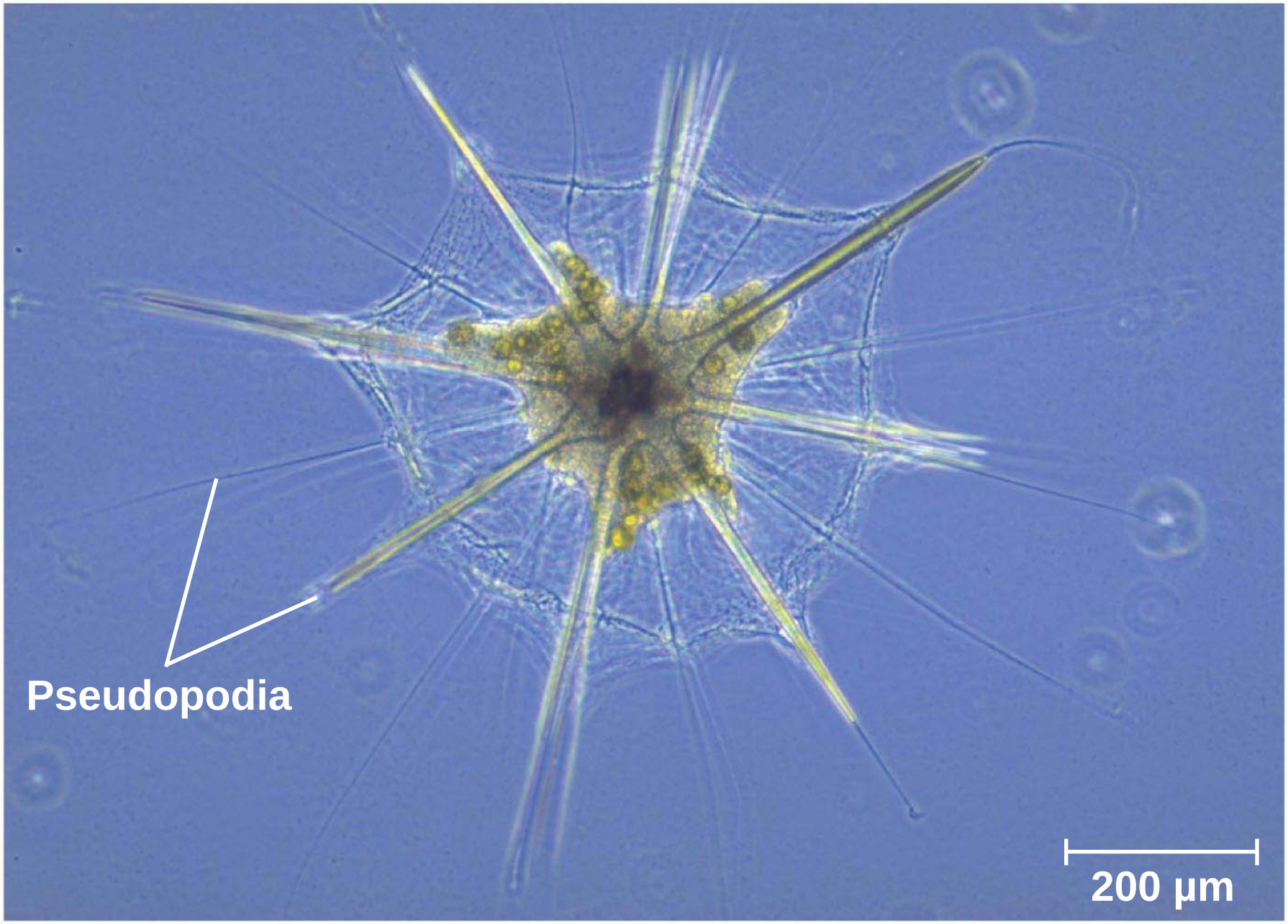
Forams

- **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

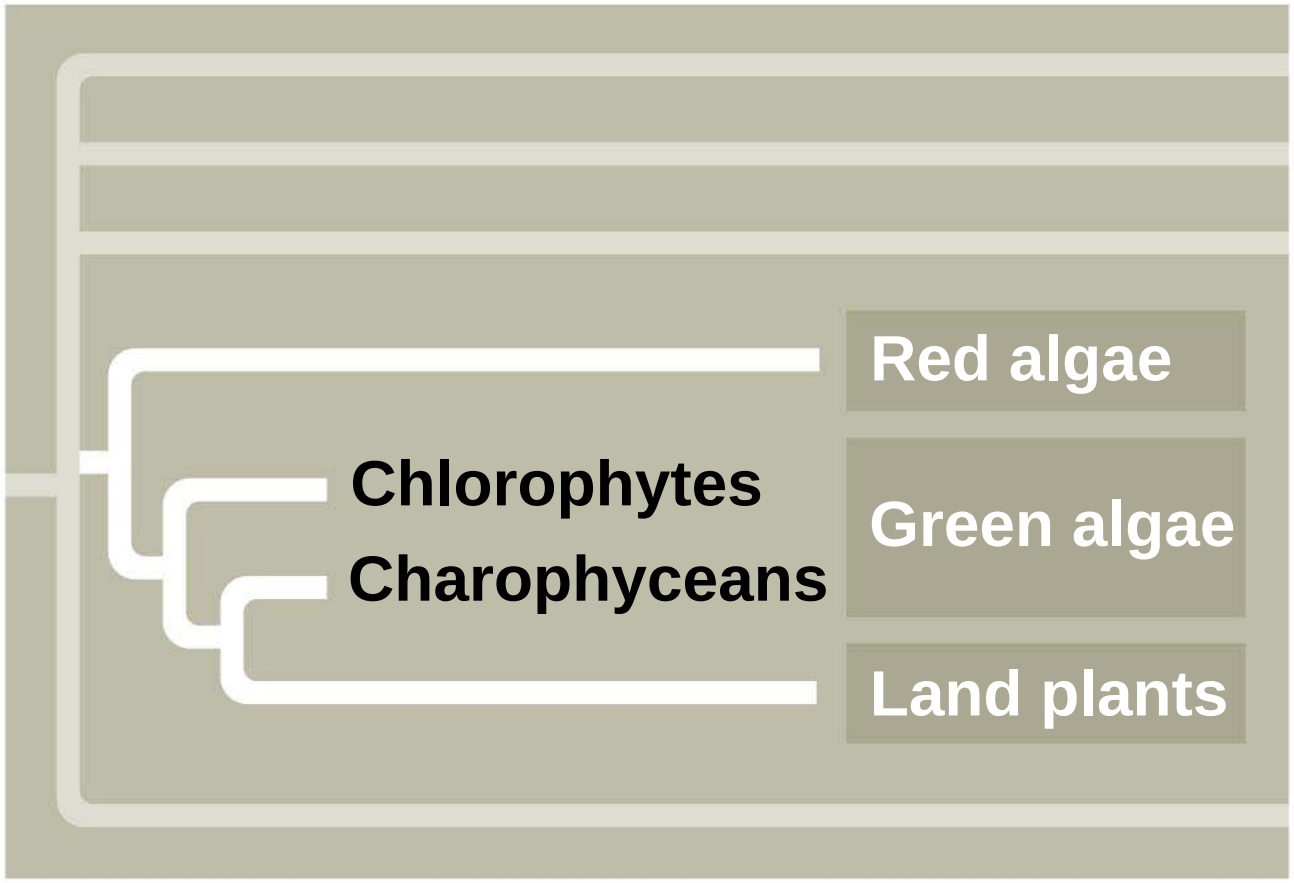
Fig. 28-18



Concept 28.5: Red algae and green algae are the closest relatives of land plants

- Over a billion years ago, a heterotrophic protist acquired a cyanobacterial endosymbiont
- The photosynthetic descendants of this ancient protist evolved into red algae and green algae
- Land plants are descended from the green algae
- **Archaeplastida** is a supergroup used by some scientists and includes red algae, green algae, and land plants

Fig. 28-UN4



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

Fig. 28-19

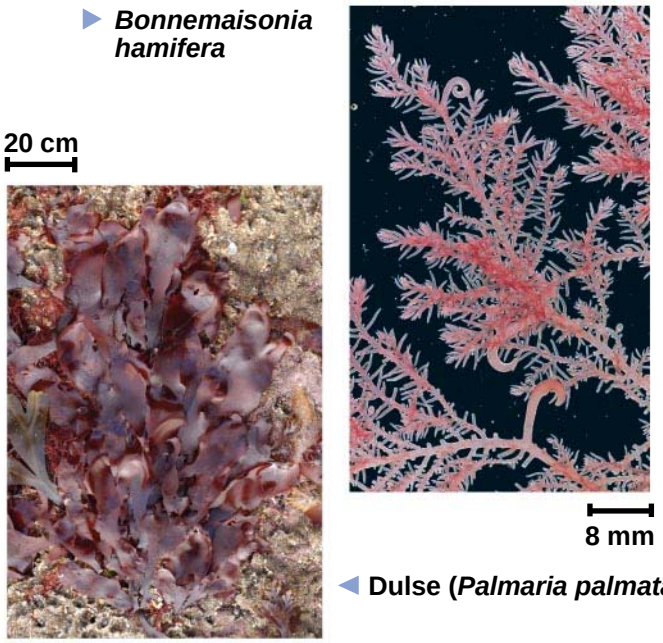


Fig. 28-19a

- ***Bonnemaisonia hamifera***

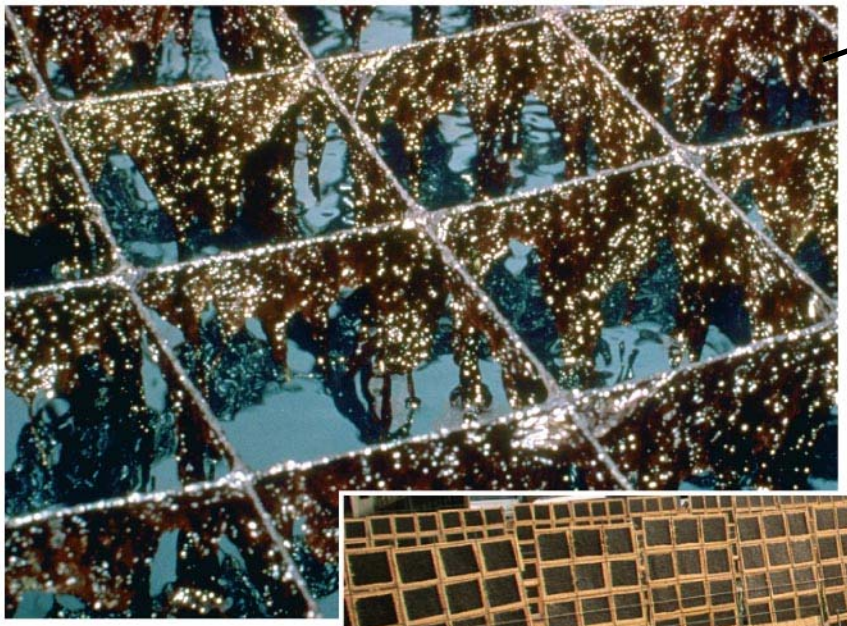
8 mm

Fig. 28-19b

◀ **Dulse (*Palmaria palmata*)**

Fig. 28-19c

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.

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

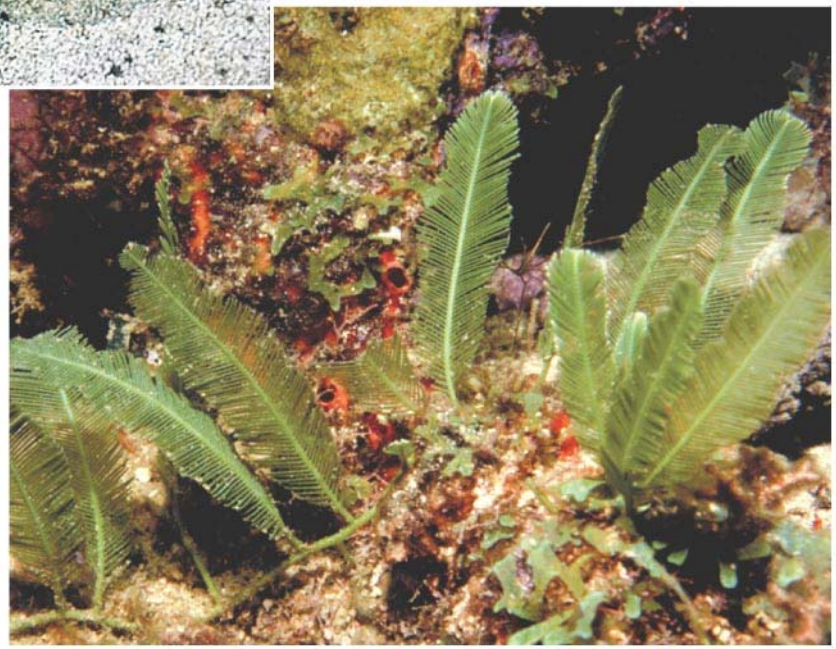
Fig. 28-20

- Chlorophytes include unicellular, colonial, and multicellular forms

Fig. 28-21

(a) *Ulva*, or sea lettuce

2 cm



(b) *Caulerpa*, an intertidal chloro-phyte

Fig. 28-21a

(a) *Ulva*, or sea lettuce

2 cm

Fig. 28-21b

(b) *Caulerpa,* an intertidal chloro-phyte

- Most chlorophytes have complex life cycles with both sexual and asexual reproductive stages

PLAY Video: *Chlamydomonas*

Fig. 28-22-1

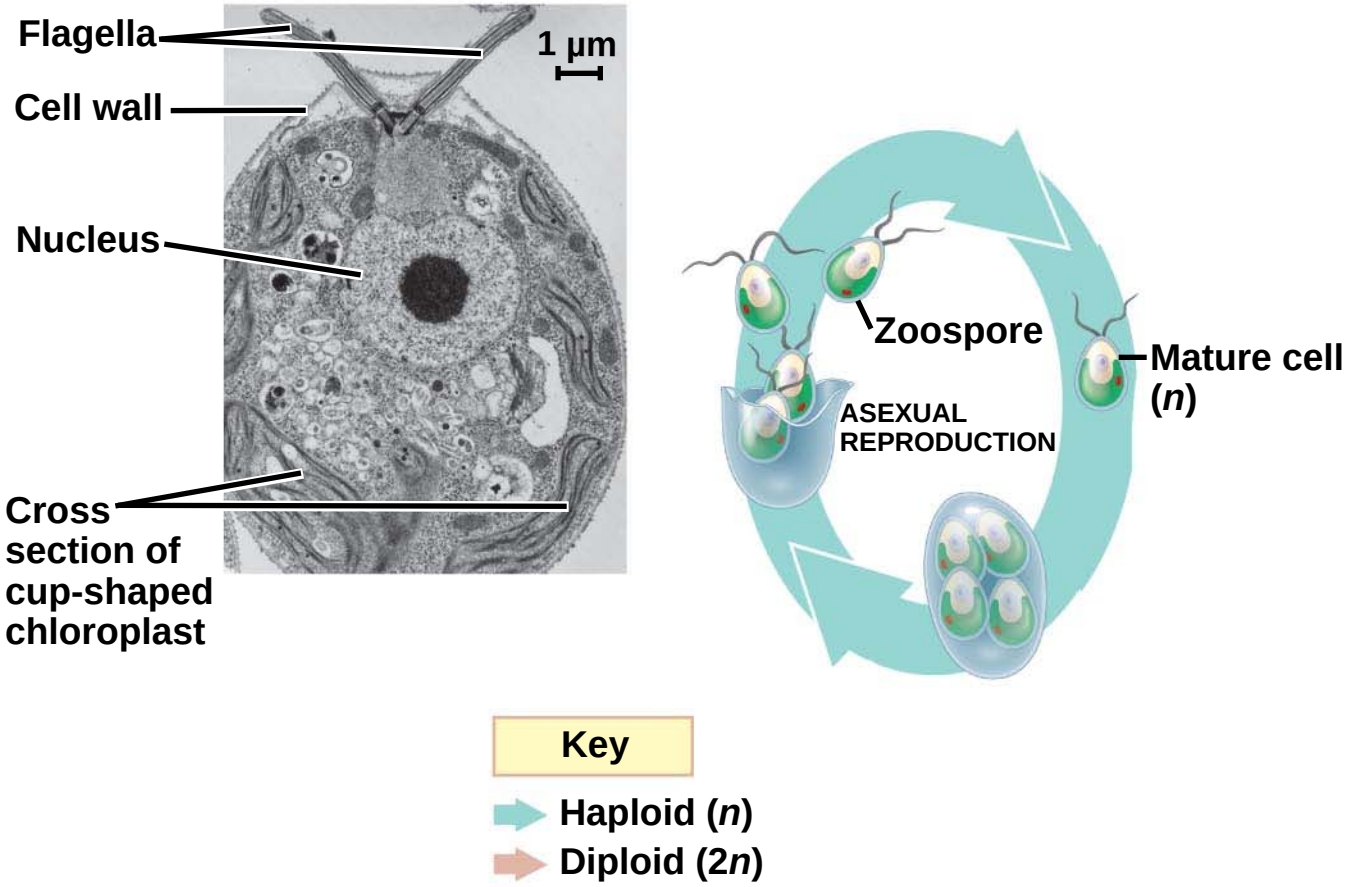
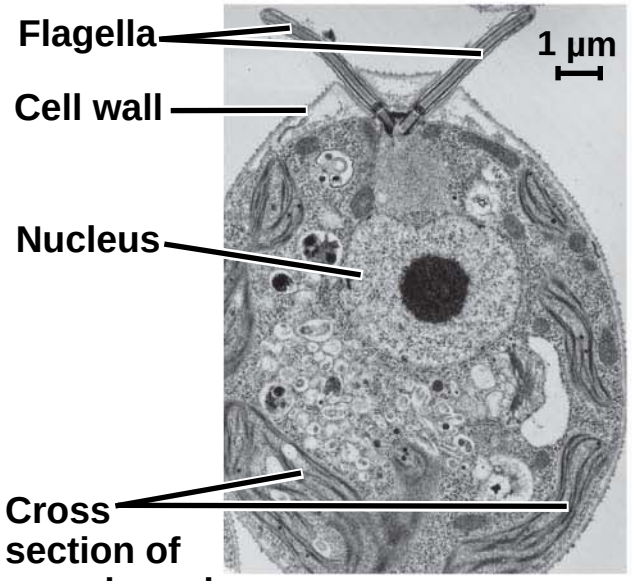
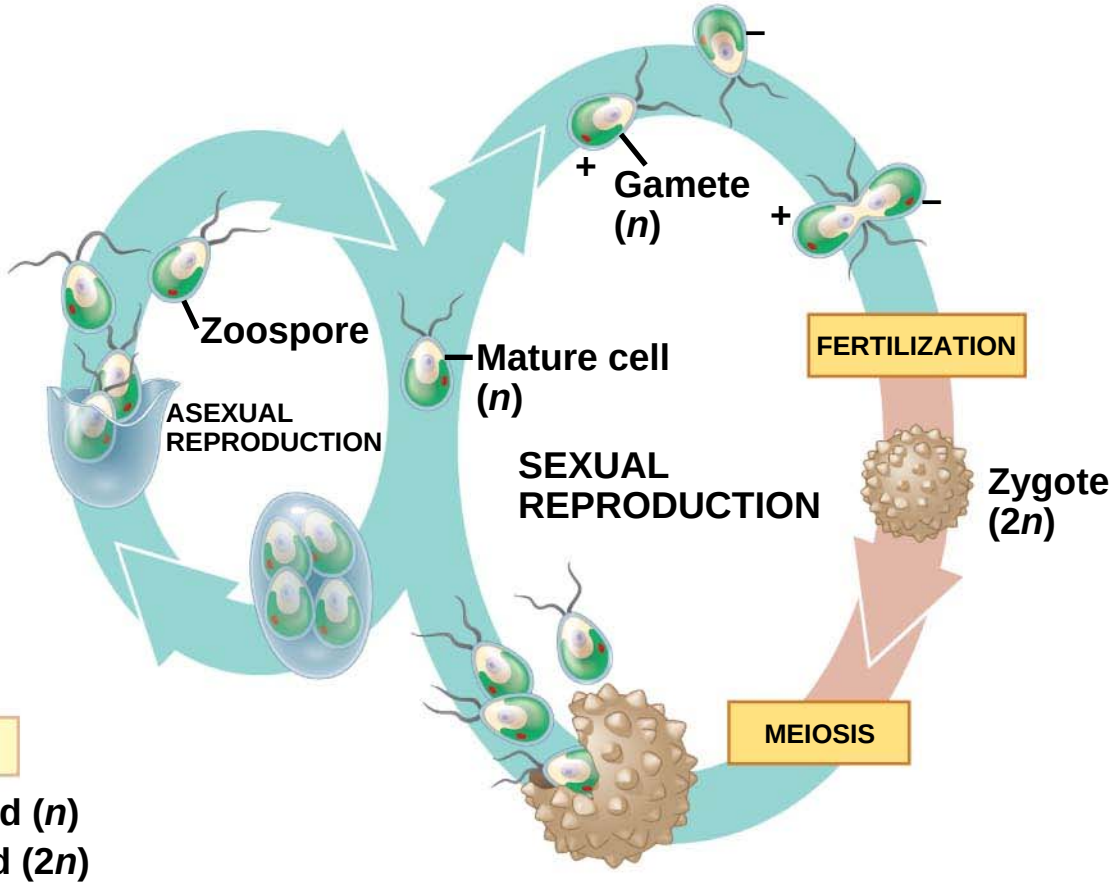


Fig. 28-22-2





Concept 28.6: Unikonts include protists that are closely related to fungi and animals

- The supergroup **Unikonta** includes animals, fungi, and some protists
- This group includes two clades: the amoebozoans and the opisthokonts (animals, fungi, and related protists)
- The root of the eukaryotic tree remains controversial
- It is unclear whether unikonts separated from other eukaryotes relatively early or late

Fig. 28-UN5

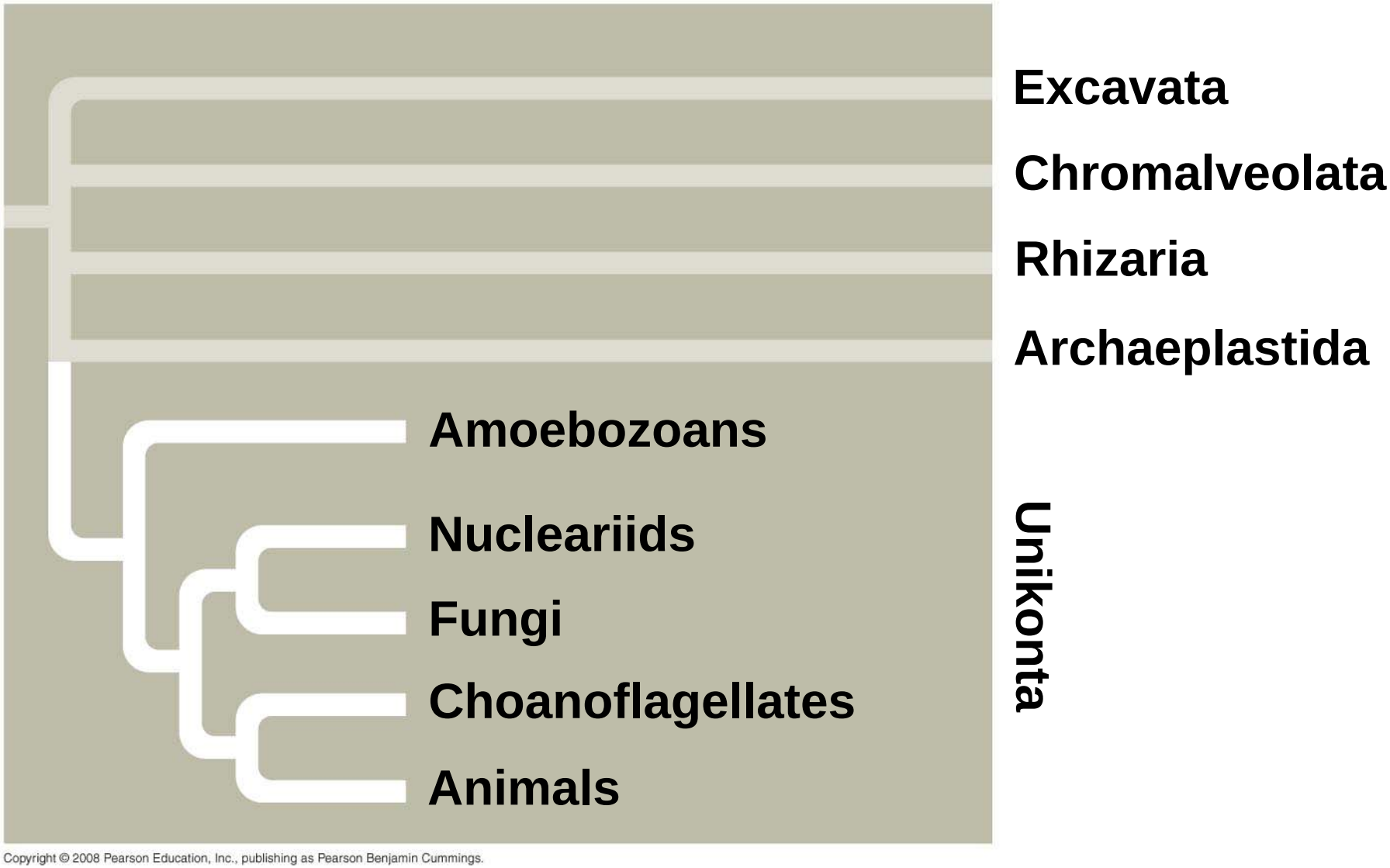
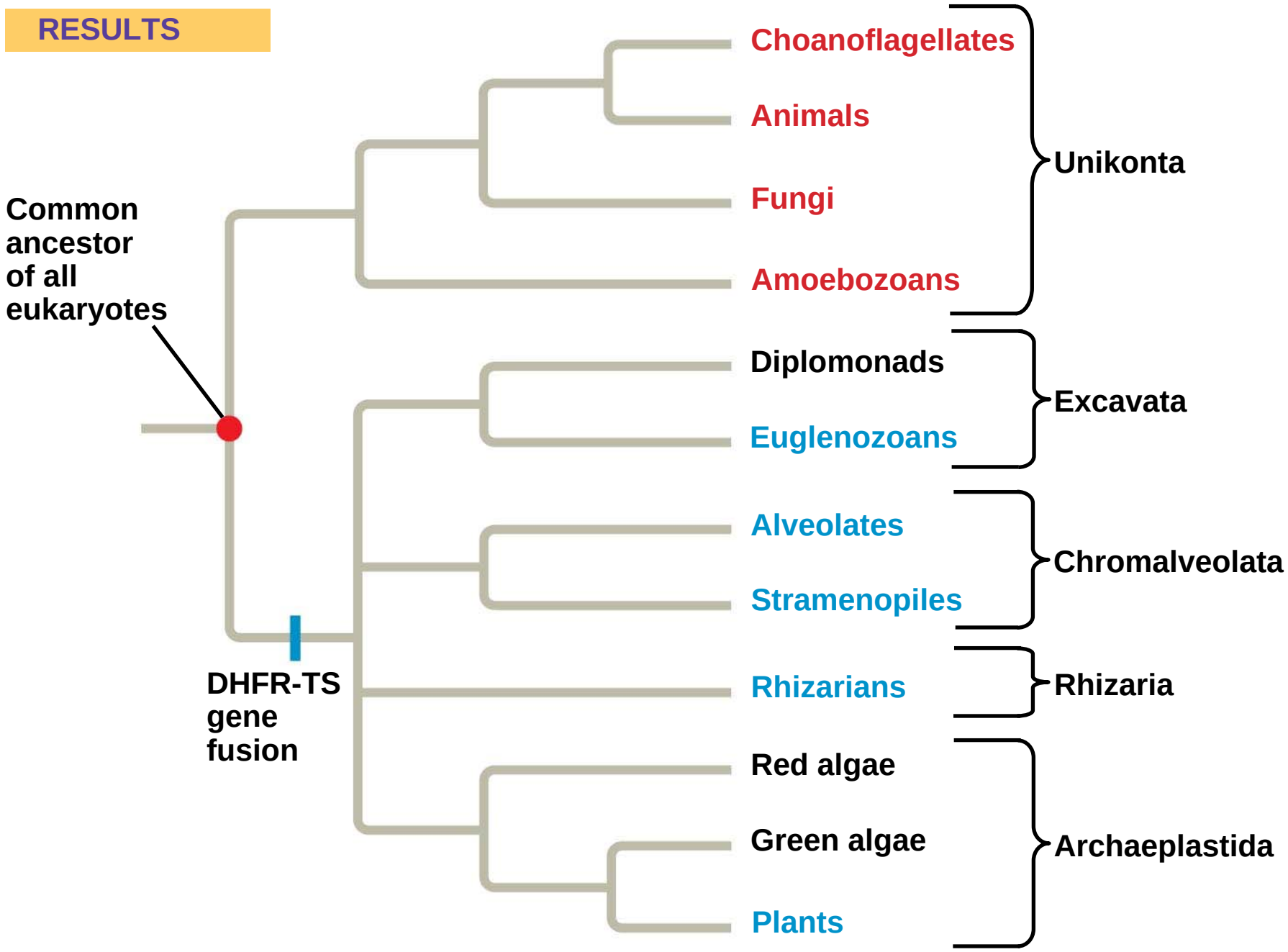


Fig. 28-23



Amoebozoans

- **Amoebozoans** are amoeba that have lobe- or tube-shaped, rather than threadlike, pseudopodia
- They include gymnamoebas, entamoebas, and slime molds

Slime Molds

- Slime molds, or mycetozoans, were once thought to be fungi
- Molecular systematics places slime molds in the clade Amoebozoa

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

Fig. 28-24-1

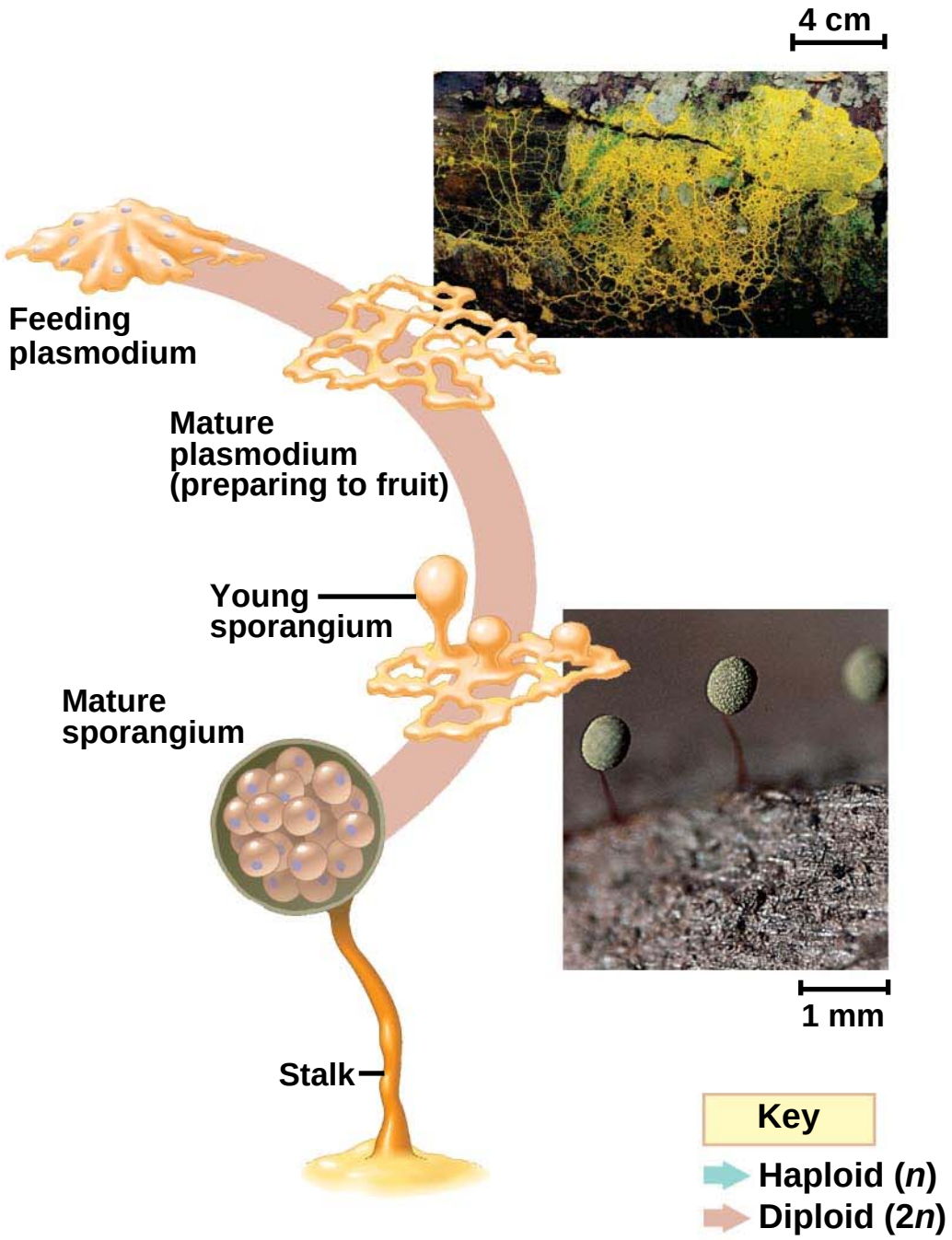


Fig. 28-24-2

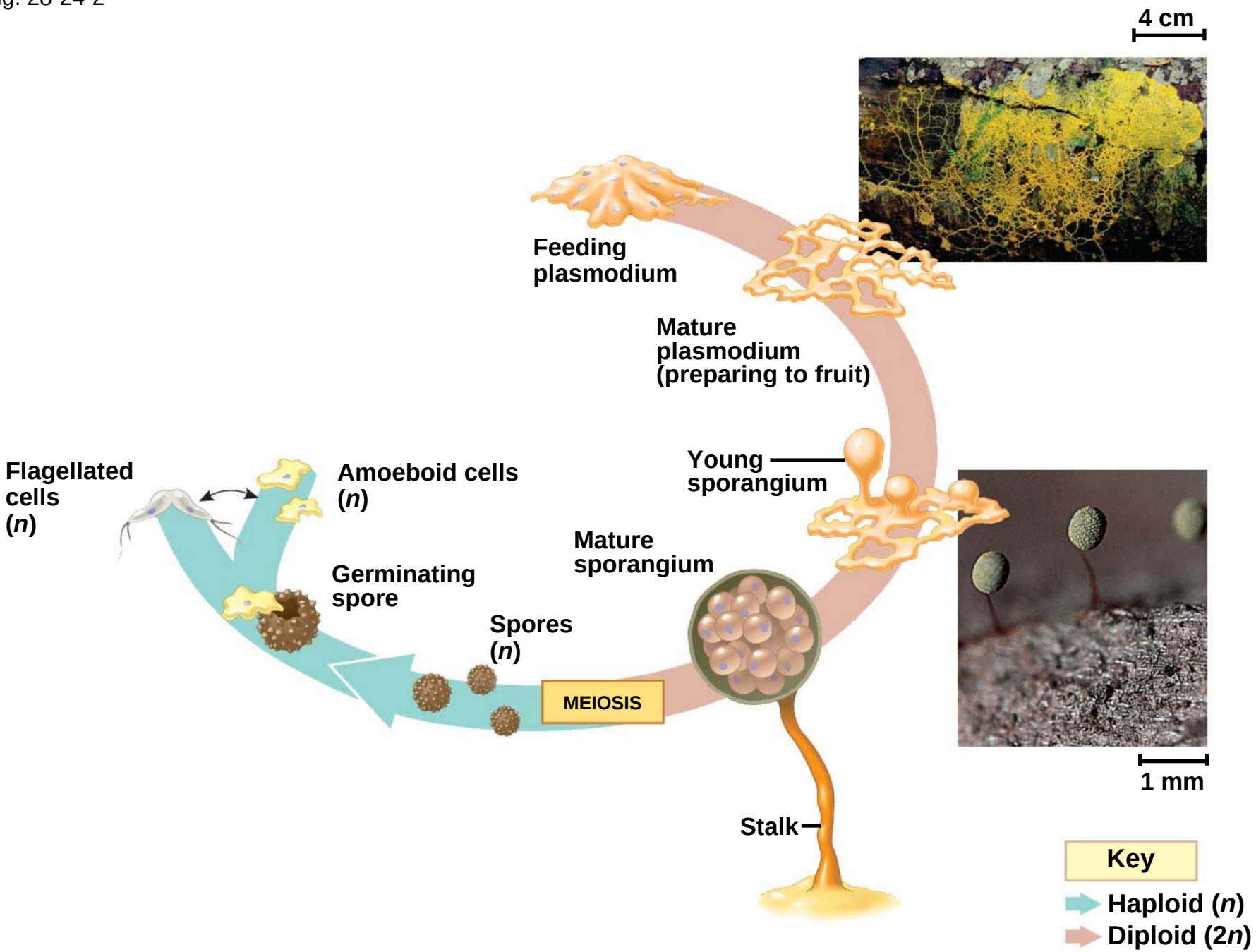
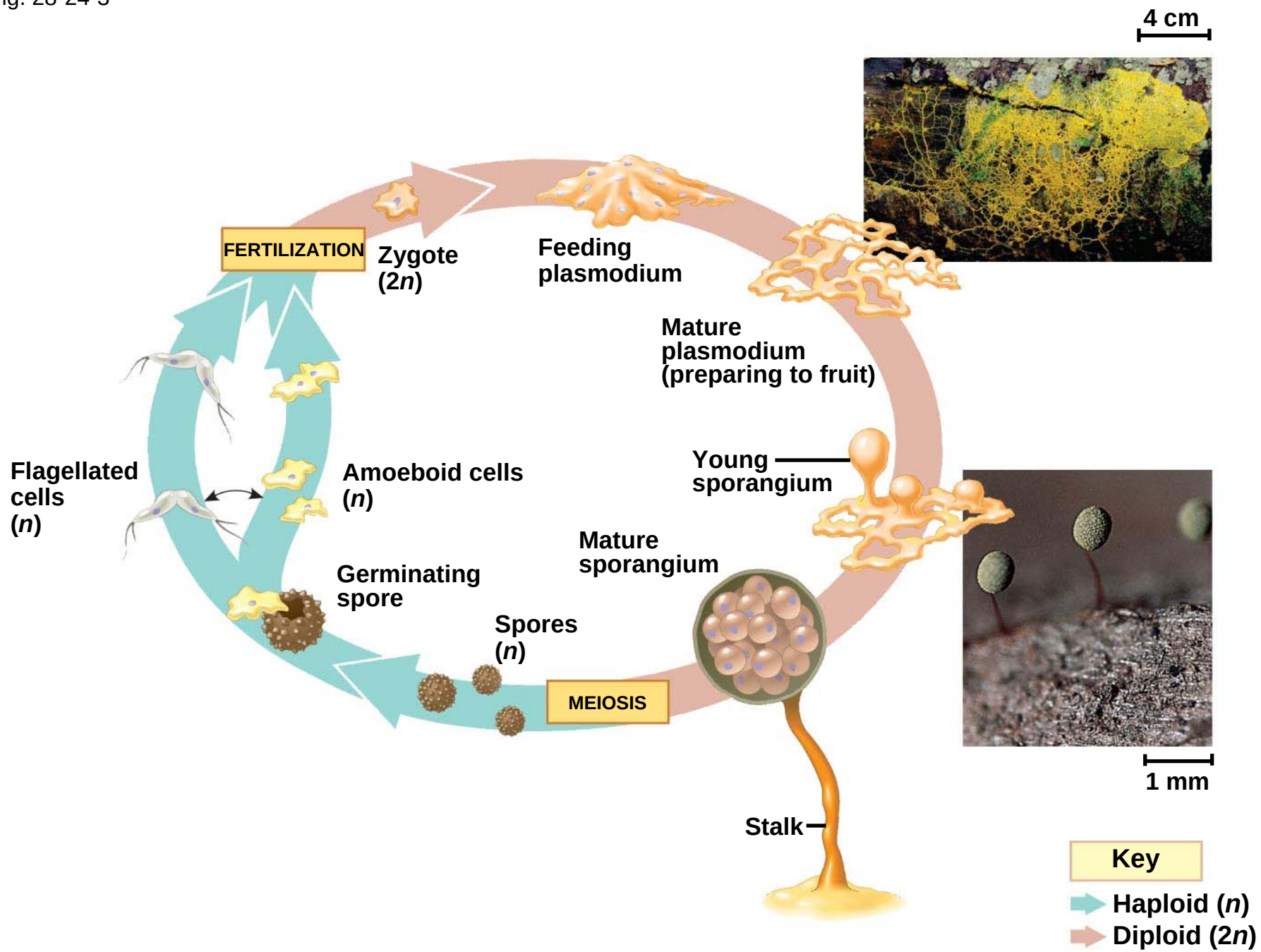


Fig. 28-24-3



- At one point in the life cycle, plasmodial slime molds form a mass called a **plasmodium** (not to be confused with malarial *Plasmodium*)
- The plasmodium is undivided by membranes and contains many diploid nuclei
- It extends pseudopodia through decomposing material, engulfing food by phagocytosis

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

Fig. 28-25-1

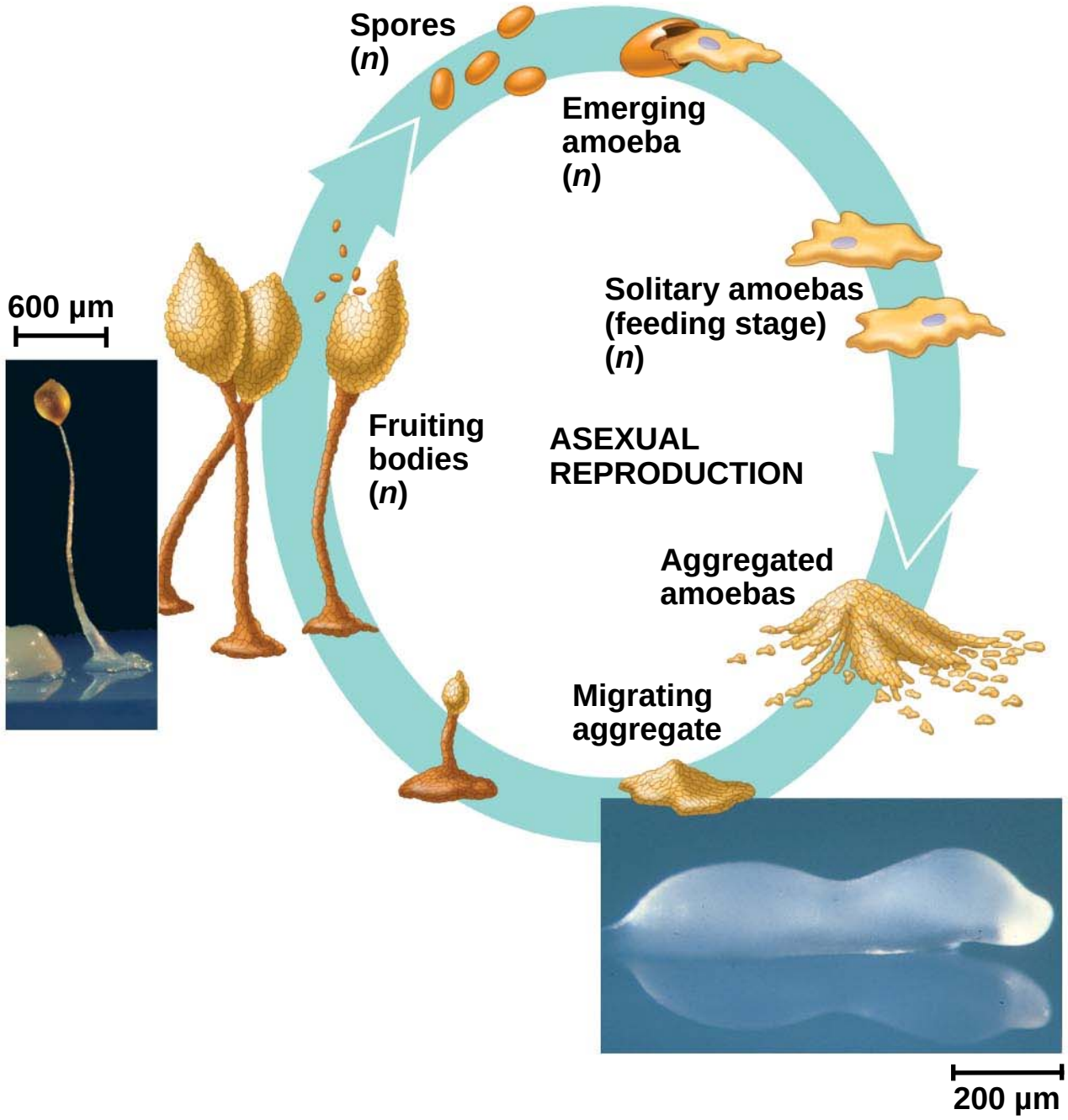
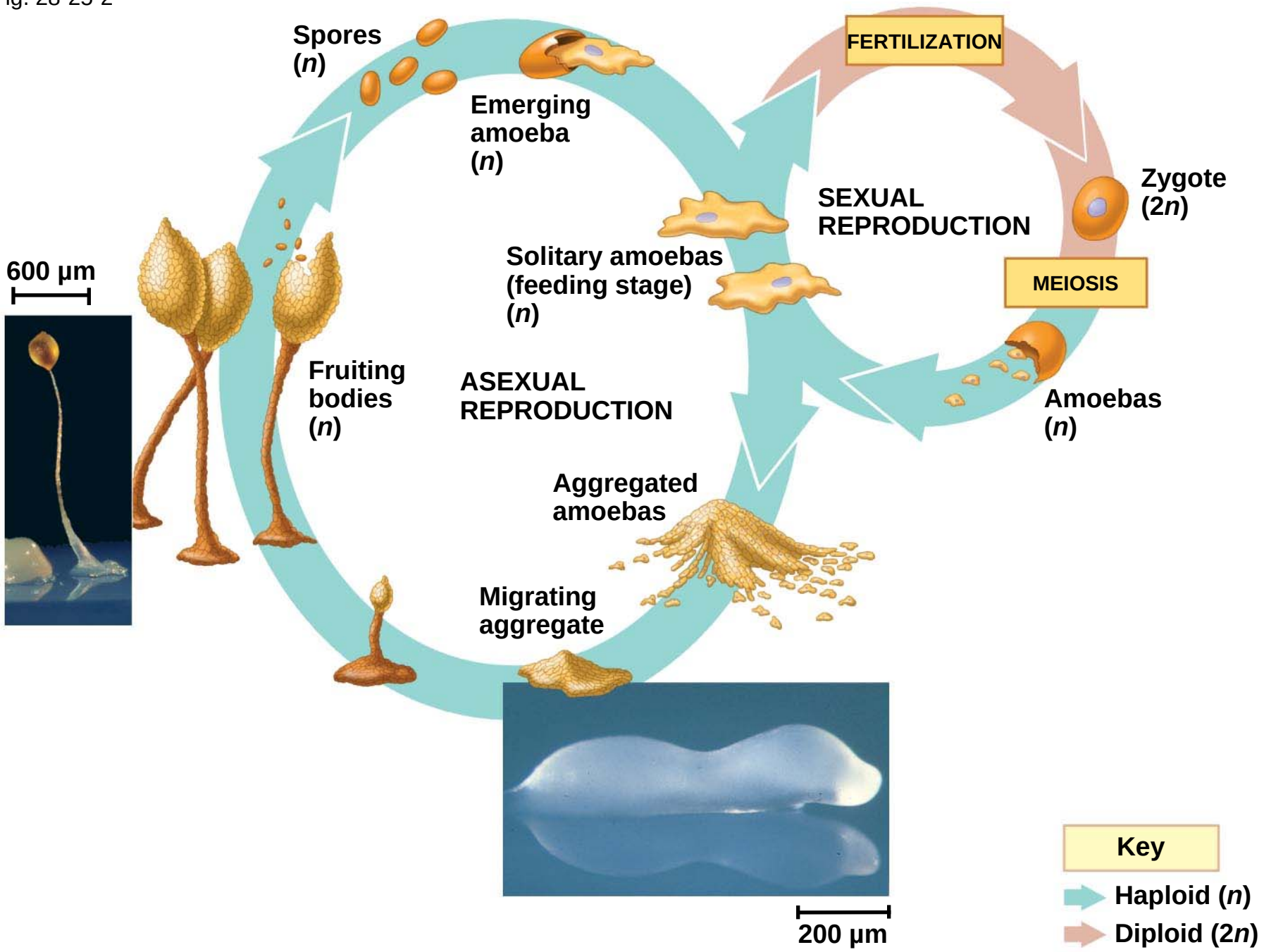


Fig. 28-25-2



Gymnamoebas

- Gymnamoebas are common unicellular amoebozoans in soil as well as freshwater and marine environments
- Most gymnamoebas are heterotrophic and actively seek and consume bacteria and other protists

PLAY Video: Amoeba

PLAY Video: Amoeba Pseudopodia

Entamoebas

- Entamoebas are parasites of vertebrates and some invertebrates
- *Entamoeba histolytica* causes amebic dysentery in humans

Opisthokonts

- **Opisthokonts** include animals, fungi, and several groups of protists

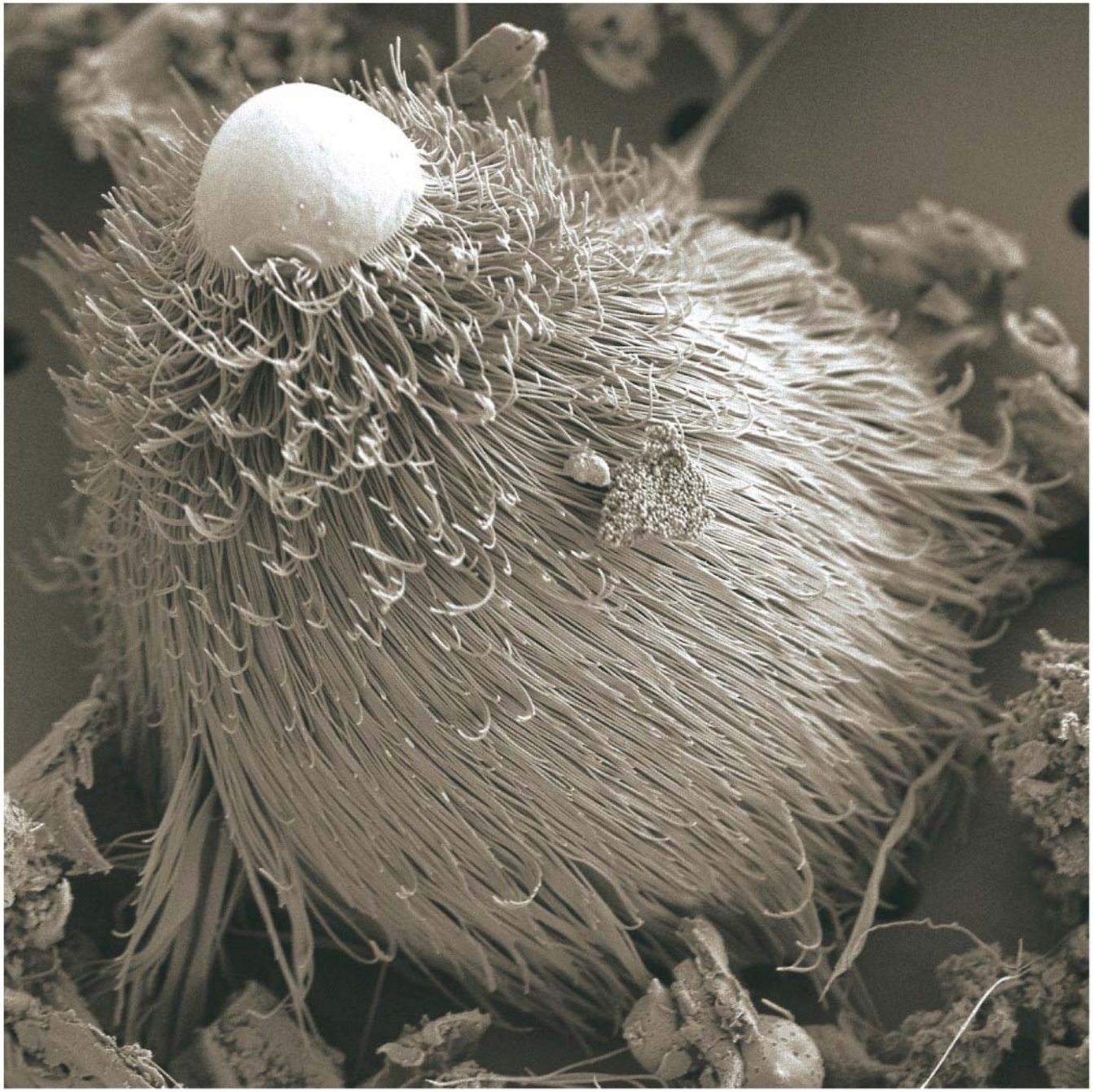
Concept 28.7: Protists play key roles in ecological relationships

- Protists are found in diverse aquatic environments
- Protists often play the role of symbiont or producer

Symbiotic Protists

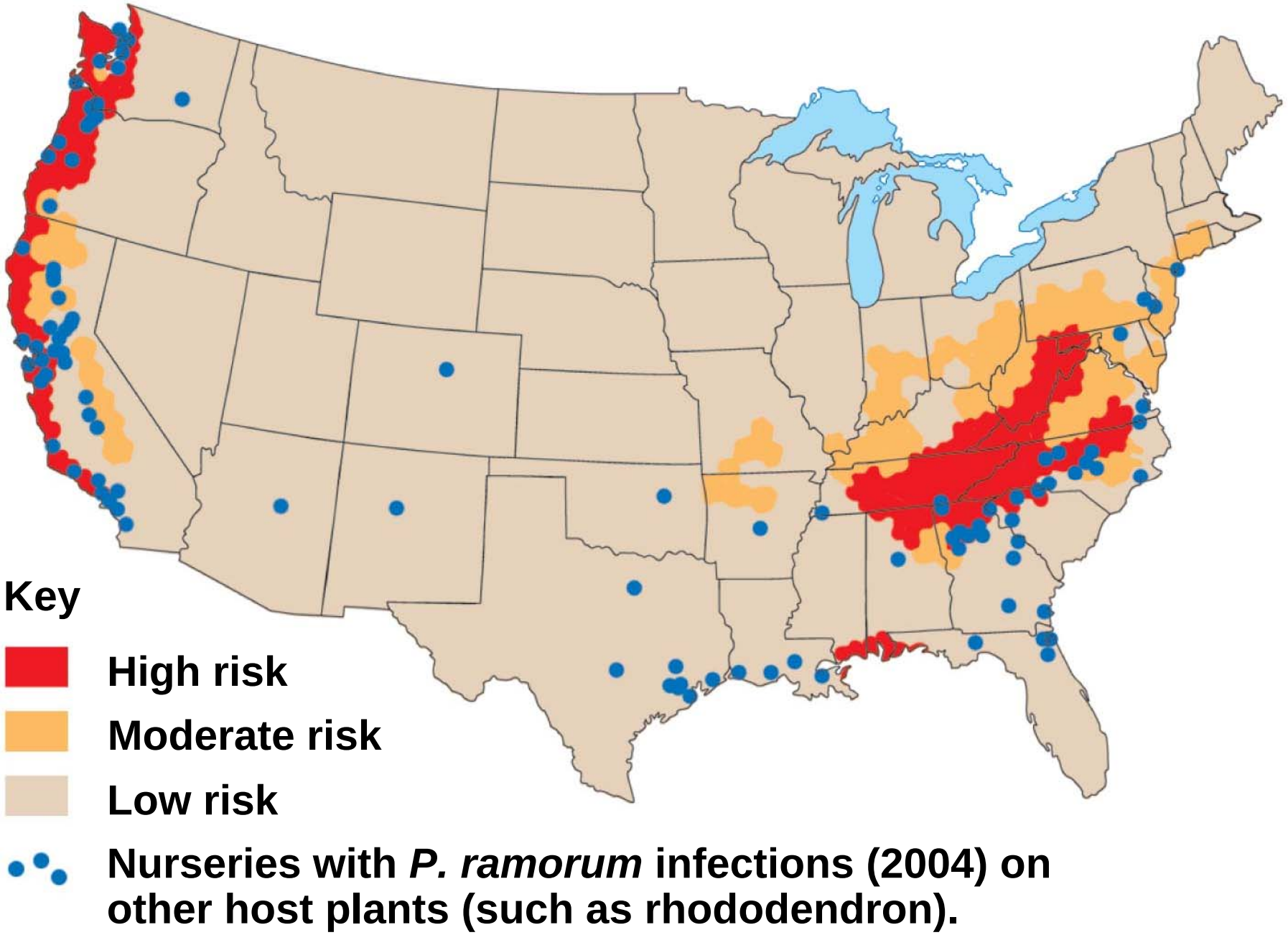
- Some protist symbionts benefit their hosts
  - Dinoflagellates nourish coral polyps that build reefs
  - Hypermastigotes digest cellulose in the gut of termites

Fig. 28-26



- Some protists are parasitic
  - *Plasmodium* causes malaria
  - *Pfesteria shumwayae* is a dinoflagellate that causes fish kills
  - *Phytophthora ramorum* causes sudden oak death

Fig. 28-27



Photosynthetic Protists

- Many protists are important **producers** that obtain energy from the sun
- In aquatic environments, photosynthetic protists and prokaryotes are the main producers
- The availability of nutrients can affect the concentration of protists

Fig. 28-28

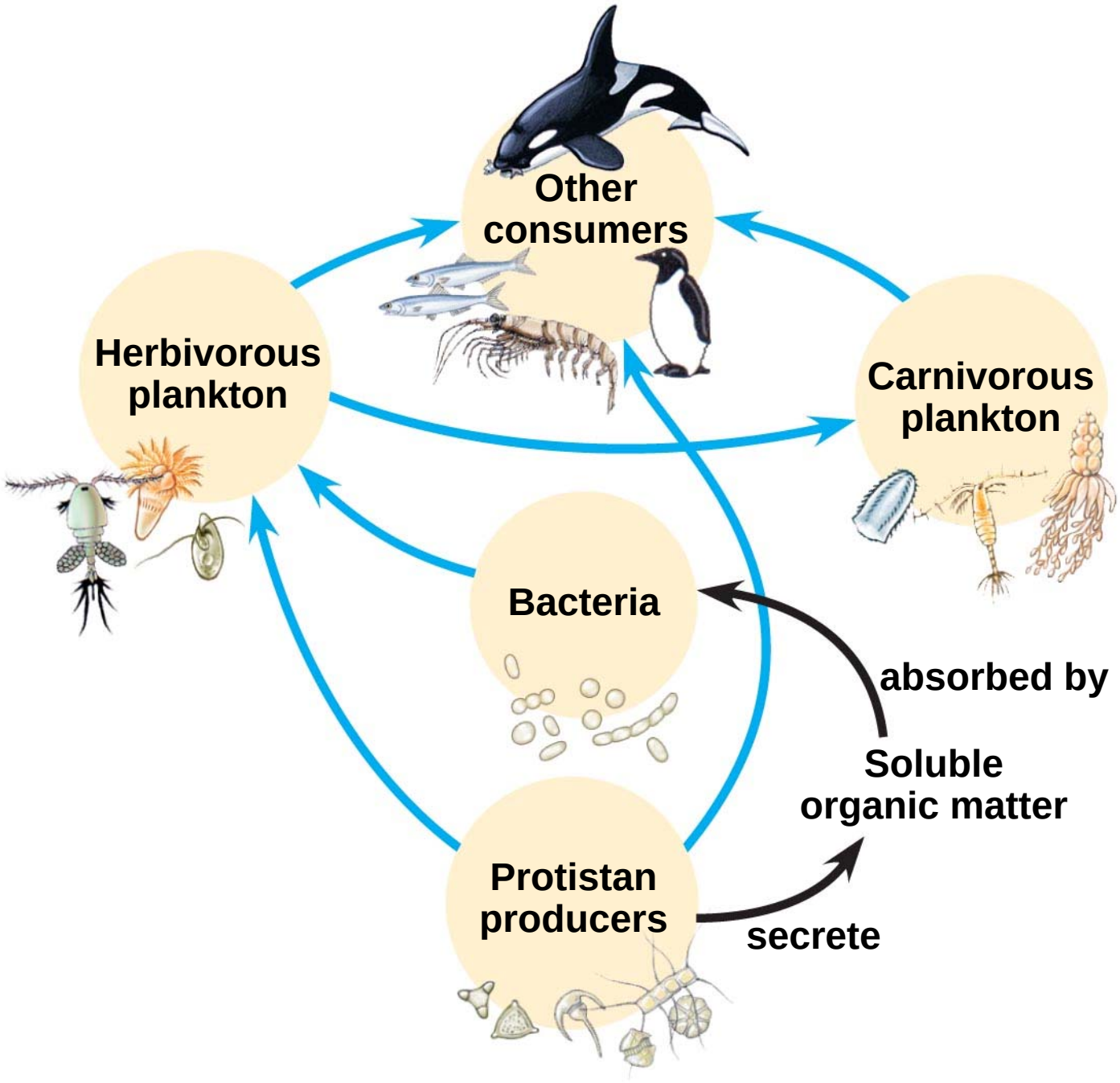


Fig. 28-UN6

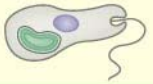
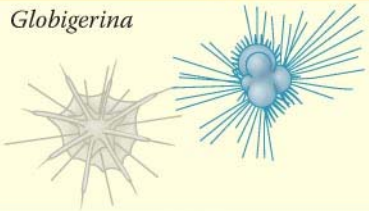
Key Concept/Eukaryote Supergroup	Major Clades	Key Morphological Characteristics	Specific Examples
Concept 28.2 **Excavates** include protists with modified mitochondria and protists with unique flagella (pp. 580–581)	**Diplomonads and parabasalids**	Modified mitochondria	*Giardia*, *Trichomonas* 
	Euglenozoans Kinetoplastids Euglenids	Spiral or crystalline rod inside flagella	*Trypanosoma*, *Euglena* 
Concept 28.3 **Chromalveolates** may have originated by secondary endosymbiosis (pp. 582–589)	**Alveolates** Dinoflagellates Apicomplexans Ciliates	Membrane-bounded sacs (alveoli) beneath plasma membrane	*Pfiesteria*, *Plasmodium*, *Paramecium* 
	Stramenopiles Oomycetes Diatoms Golden algae Brown algae	Hairy and smooth flagella	*Phytophthora*, *Laminaria* 
Concept 28.4 **Rhizarians** are a diverse group of protists defined by DNA similarities (pp. 589–590)	**Forams**	Amoebas with threadlike pseudopodia and a porous shell	*Globigerina* 
	Radiolarians	Amoebas with threadlike pseudopodia radiating from central body	
Concept 28.5 Red algae and green algae are the closest relatives of land plants (pp. 590–592—**Archaeplastida**)	**Red algae**	Phycoerythrin (accessory pigment)	*Porphyra* 
	Green algae	Plant-type chloroplasts	*Chlamydomonas*, *Ulva* 
	Land plants	(See Chapters 29 and 30.)	Mosses, ferns, conifers, flowering plants 
Concept 28.6 **Unikonts** include protists that are closely related to fungi and animals (pp. 593–596)	**Amoebozoans** Slime molds Gymnamoebas Entamoebas	Amoebas with lobe-shaped pseudopodia	*Amoeba*, *Entamoeba*, *Dictyostelium* 
	Opisthokonts	(Highly variable; see Chapters 31–34.)	Nucleariids, choanoflagellates, animals, fungi 

Fig. 28-UN6a

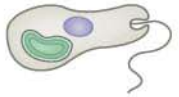
Key Concept/Eukaryote Supergroup	Major Clades	Key Morphological Characteristics	Specific Examples
Concept 28.2 **Excavates** include protists with modified mitochondria and protists with unique flagella	**Diplomonads and parabasalids**	Modified mitochondria	*Giardia*, *Trichomonas* 
	Euglenozoans Kinetoplastids Euglenids	Spiral or crystalline rod inside flagella	*Trypanosoma*, *Euglena* 

Fig. 28-UN6b

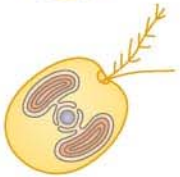
Key Concept/Eukaryote Supergroup	Major Clades	Key Morphological Characteristics	Specific Examples
Concept 28.3 **Chromalveolates** may have originated by secondary endosymbiosis	**Alveolates** Dinoflagellates Apicomplexans Ciliates	Membrane-bounded sacs (alveoli) beneath plasma membrane	*Pfiesteria*, *Plasmodium*, *Paramecium* 
	Stramenopiles Oomycetes Diatoms Golden algae Brown algae	Hairy and smooth flagella	*Phytophthora*, *Laminaria* 

Fig. 28-UN6c

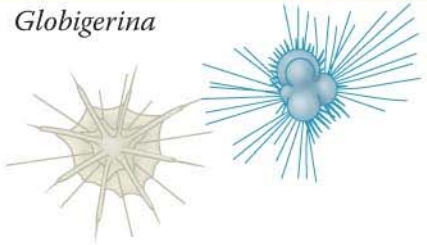
Key Concept/Eukaryote Supergroup	Major Clades	Key Morphological Characteristics	Specific Examples
Concept 28.4 **Rhizarians** are a diverse group of protists defined by DNA similarities	**Forams**	Amoebas with threadlike pseudopodia and a porous shell	*Globigerina* 
	Radiolarians	Amoebas with threadlike pseudopodia radiating from central body	

Fig. 28-UN6d

Key Concept/Eukaryote Supergroup	Major Clades	Key Morphological Characteristics	Specific Examples
Concept 28.5 Red algae and green algae are the closest relatives of land plants	**Red algae**	Phycoerythrin (accessory pigment)	*Porphyra*
	Green algae	Plant-type chloroplasts	*Chlamydomonas*, *Ulva*
	Land plants	(See Chapters 29 and 30.)	Mosses, ferns, conifers, flowering plants

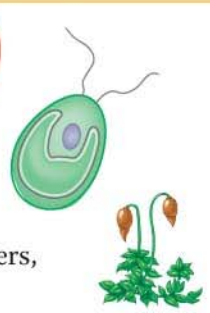


Fig. 28-UN6e

Key Concept/Eukaryote Supergroup	Major Clades	Key Morphological Characteristics	Specific Examples
Concept 28.6 **Unikonts** include protists that are closely related to fungi and animals	**Amoebozoans** Slime molds Gymnamoebas Entamoebas	Amoebas with lobe-shaped pseudopodia	*Amoeba*, *Entamoeba*, *Dictyostelium* 
	Opisthokonts	(Highly variable; see Chapters 31–34.)	Nucleariids, choanoflagellates, animals, fungi 

You should now be able to:

1. Explain why the kingdom Protista is no longer considered a legitimate taxon
2. Explain the process of endosymbiosis and state what living organisms are likely relatives of mitochondria and plastids
3. Distinguish between endosymbiosis and secondary endosymbiosis
4. Name the five supergroups, list their key characteristics, and describe some representative taxa