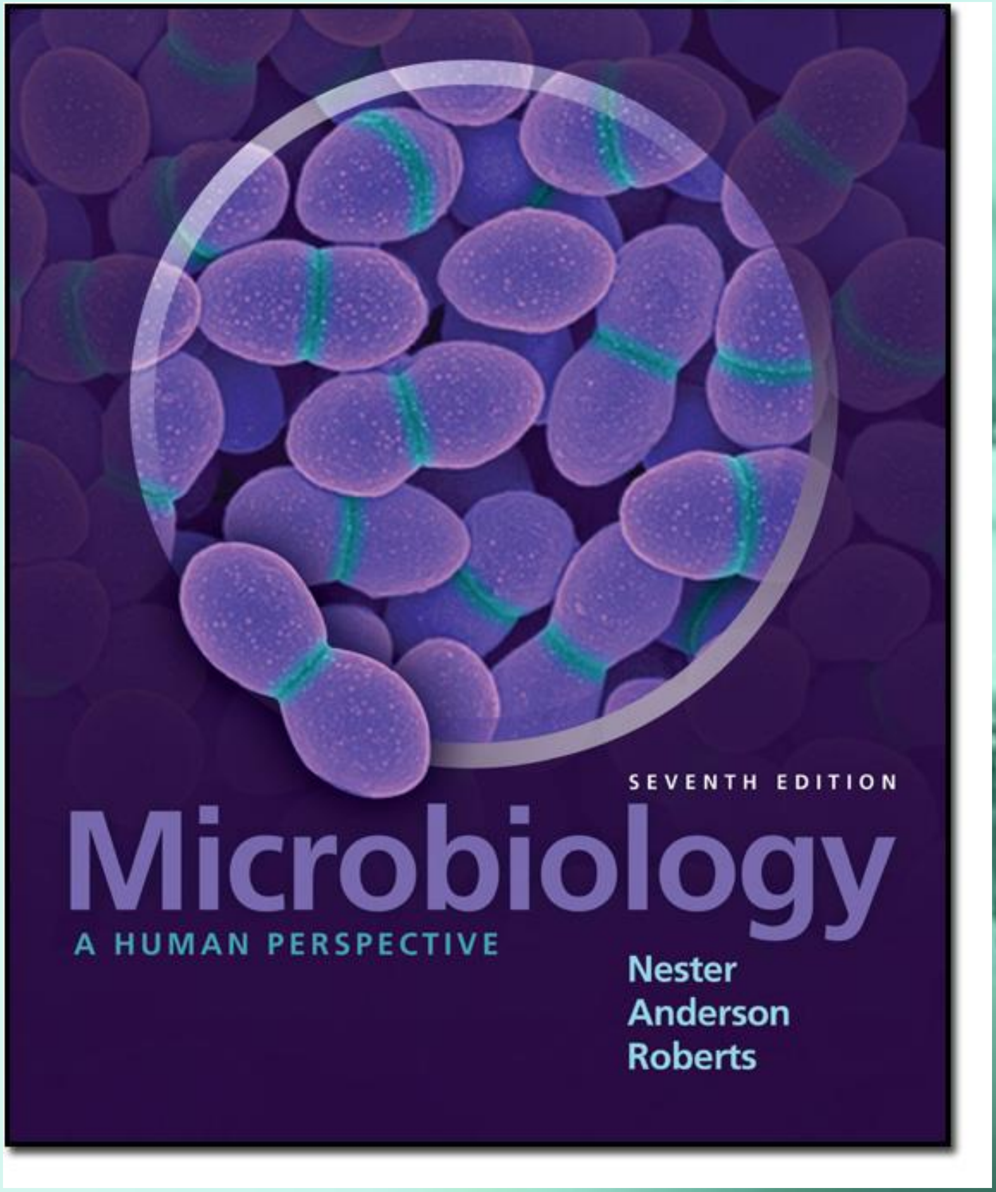

SEVENTH EDITION
Microbiology
A HUMAN PERSPECTIVE
Nester
Anderson
Roberts

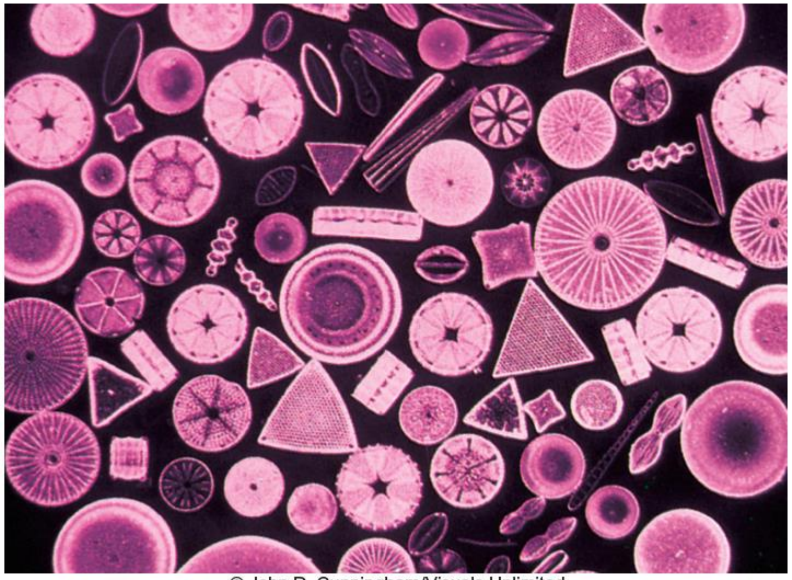
Chapter 12

A Glimpse of History

- Irish Potato Famine (1845–1847)
  - Water mold *Phytophthora infestans* decimated crop
  - Estimated 1.5 million people died during famine
  - More than 1 million emigrated to U.S., Canada
  - Population of Ireland dropped by 25%
  - Showed danger of relying on a single crop
  - Potatoes brought to Europe 200 years earlier from South America
  - Easy to grow, convenient, nearly complete food source
  - Potato blight results in nearly $10 billion/year in losses
  - In 2009, genomes of potato and *P. infestans* sequenced

A Glimpse of History

- Informal groups of microscopic eukaryotes
  - Algae: simple autotrophs (photosynthesizers)
  - Fungi: heterotrophic organisms; chitin in cell wall
  - Protozoa: microscopic heterotrophs that are not fungi
  - Protists: eukaryotes that are not fungi, plants, animals
  - Chapter 12 includes multicellular worms, certain insects since implicated in human disease
    - Often transmitted or carried in microscopic forms



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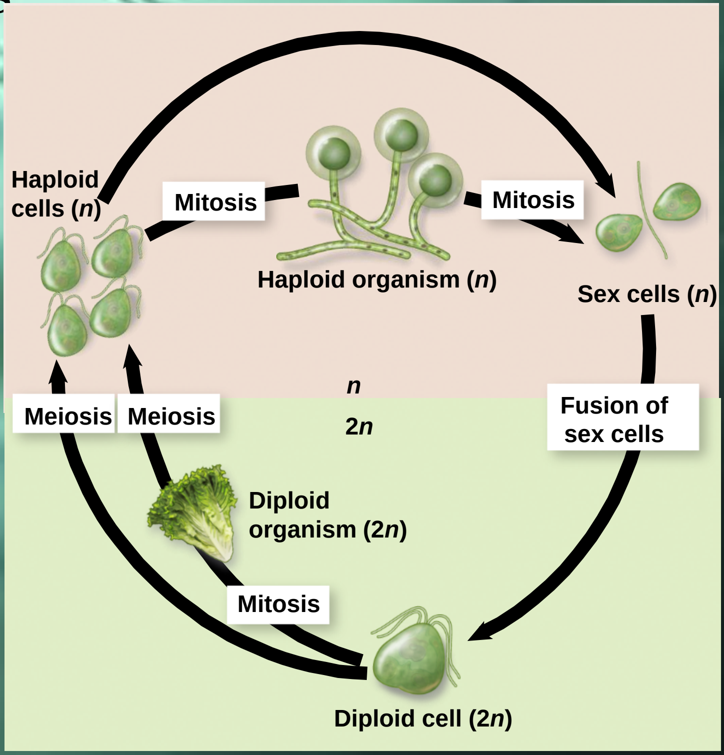
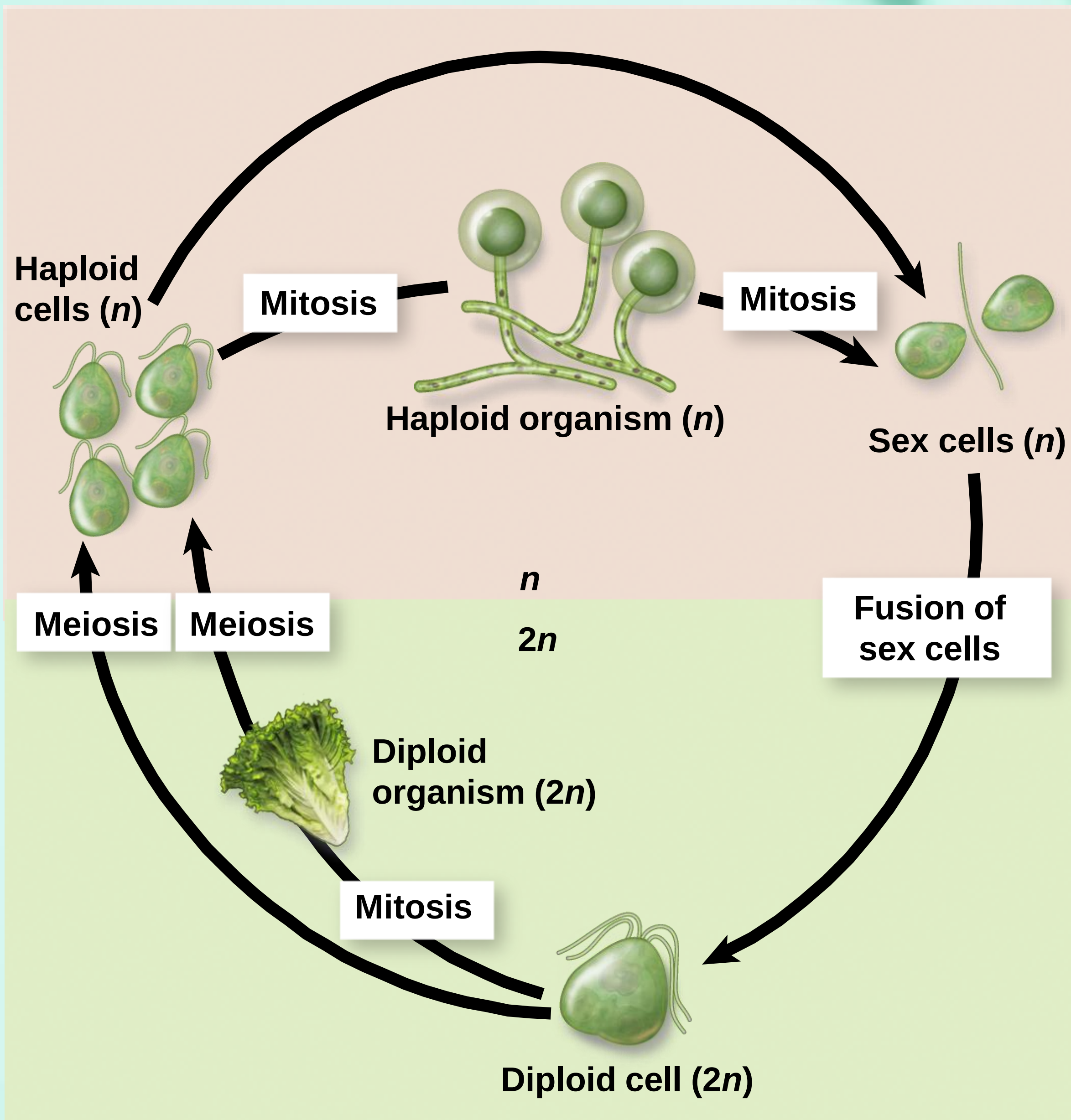
Microscopic Eukaryotes

- Eukaryotics differ from prokaryotes
  - Nucleus; membrane-bound organelles; no peptidoglycan; usually well-developed cytoskeleton
  - May be haploid and/or diploid
  - Asexual reproduction via mitosis
  - Sexual reproduction via meiosis
    - Diploid cells produce haploid cells
    - Can develop into haploid organisms or gametes
    - Fusion of 2 gametes yields diploid cell; recombination of genetic material

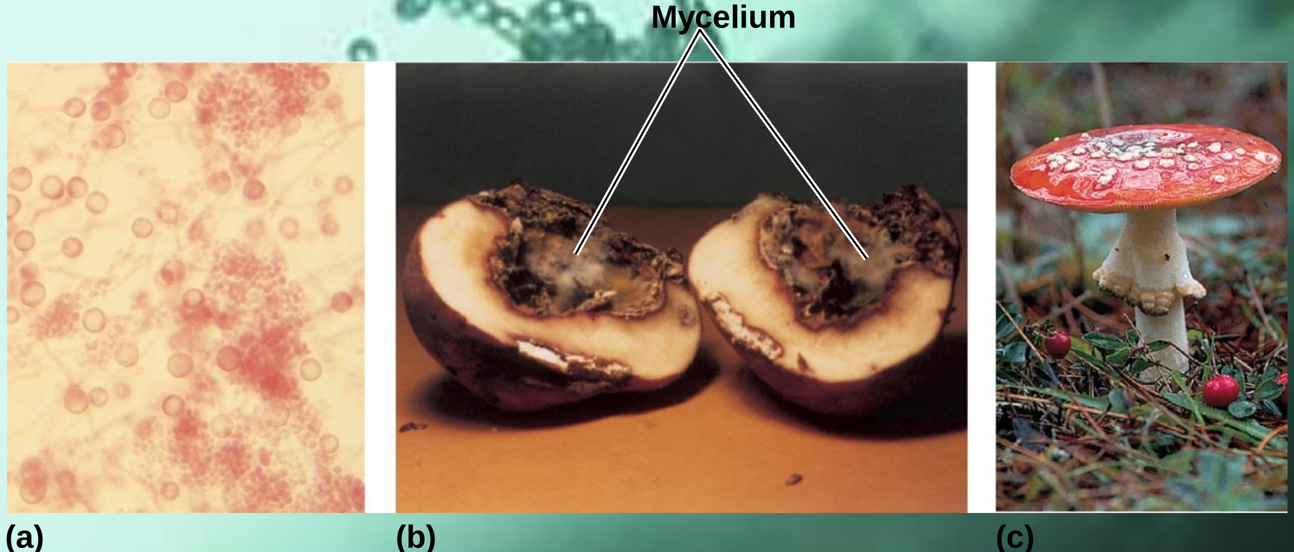




Haploid
cells (*n*)
Mitosis
Haploid organism (*n*)
Mitosis
Sex cells (*n*)
n
2*n*
Meiosis
Meiosis
Fusion of
sex cells
Diploid
organism (2*n*)
Mitosis
Diploid cell (2*n*)

12.1. Fungi

- Fungi: molds, yeasts, mushrooms
  - Refers to morphological forms, not classification
  - Yeasts: single-celled fungi
  - Molds: filamentous fungi
  - Mushrooms: reproductive structures of certain fungi
    - Mycology is study of mushrooms



12.1. Fungi

- Fungi: cell wall contains chitin
  - Fungal membranes typically have ergosterol
  - Fungi excrete enzymes to degrade larger molecules
  - Along with bacteria, principle decomposers
    - Can degrade cellulose and lignin (wood)
    - Releases CO_2, nitrogen compounds into soils
  - Saprophytic: nutrients from dead or decaying matter
  - Some act as parasites of living tissue
    - Few infect humans; plant infections common
  - Some fungi form symbiotic relationships (e.g., lichens)

12.1. Fungi

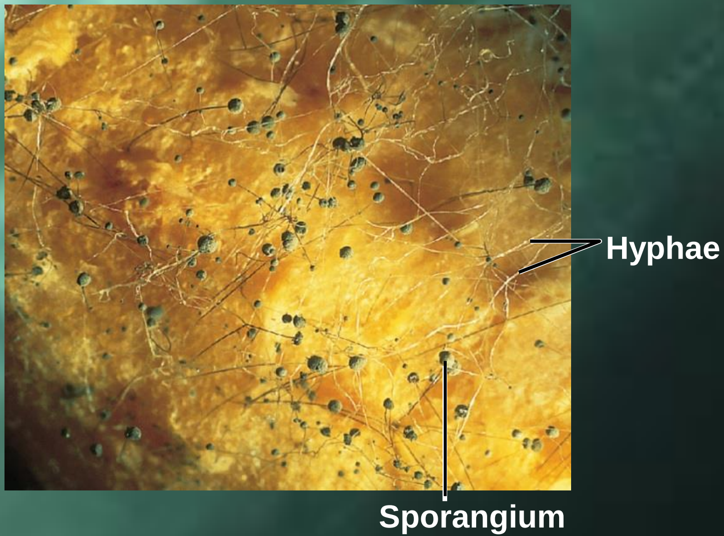
- Classification of fungi in state of flux
  - ~80,000 recognized species; likely over 1 million total
  - Chapter 12 considers only 4 major groups

TABLE 12.1 Characteristics of Major Groups of Fungi

Group and Representative Member(s)	Appearance	Usual Habitat	Some Distinguishing Characteristics	Asexual Reproduction	Sexual Reproduction
Chytridiomycetes *Batrachochytrium dendrobatidis*		Aquatic, guts of herbivores, parasitic	Unicellular and multicellular. Rhizoids with no true mycelium	Motile zoospores from a sporangium	Flagellated gametes in male and female
Zygomycetes *Rhizopus stolonifer* (black bread mold)		Terrestrial	Multicellular, mycelia of continuous hyphae with many haploid nuclei	Asexual spores develop in sporangia on the tips of aerial hyphae	Sexual spores known as zygospores can remain dormant in adverse environment
Ascomycetes *Neurospora, Saccharomyces cerevisiae* (baker's yeast) *Penicillium, Aspergillus*		Terrestrial, on fruit and other organic materials	Unicellular and multicellular with septated mycelia	Is common by budding; conidiospores	Involves the formation of an ascus (sac) on specialized hyphae
Basidiomycetes *Agaricus campestris* (meadow mushroom) *Cryptococcus neoformans*		Terrestrial	Multicellular, uninucleated mycelia; group includes mushrooms, smuts, rusts that affect the food supply	Commonly absent	Produce basidiospores that are borne on club-shaped structures at the tips of the hyphae

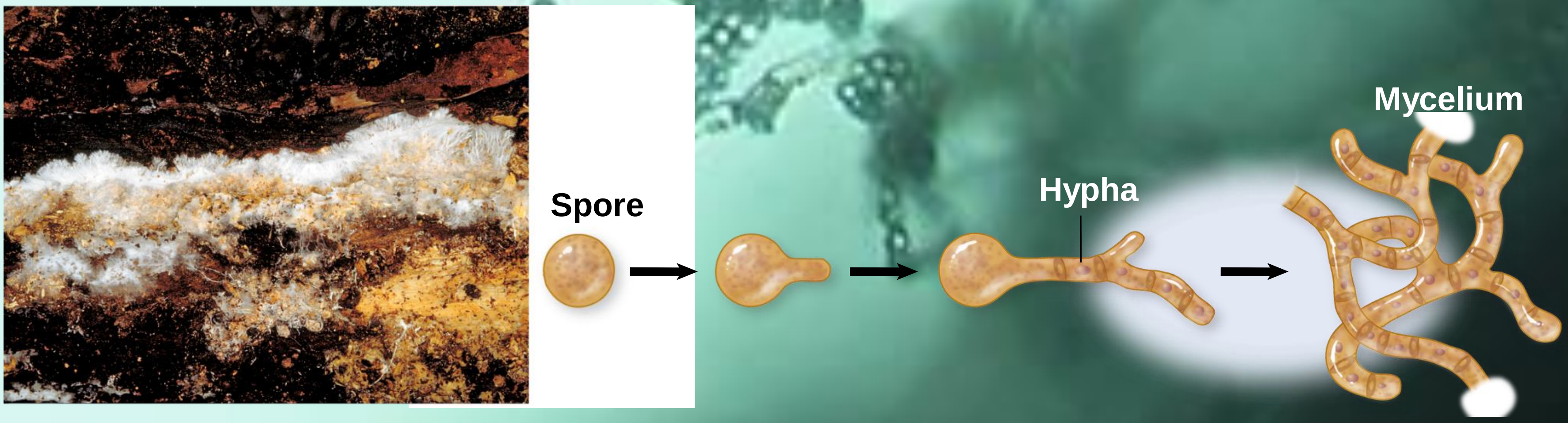
12.1. Fungi

- Classification of fungi (continued...)
  - Chytrids usually live in water; some in mammalian gut
    - Some parasitic: *B. dendrobatidis* infects frogs
    - Only fungi with motile forms: reproductive cells
  - Zygomycetes include black bread mold *Rhizopus*
    - Reproductive structures called sporangia
  - Ascomycetes (sac fungi) include ~75% of known fungi
    - *Penicillium*; pathogens; morels and truffles; lichens
  - Basidiomycetes (club fungi) include mushrooms, plant parasites (smuts, rusts)



12.1. Fungi

- Structure of Fungi
  - Most fungi multicellular; composed of hyphae
    - Visible mass of hyphae termed mycelium
    - Tips of hyphae grow rapidly in direction of food source, grow throughout food; openings remain between cells allowing movement along hypha
    - High surface-to-volume ratio aids nutrient absorption



12.1. Fungi

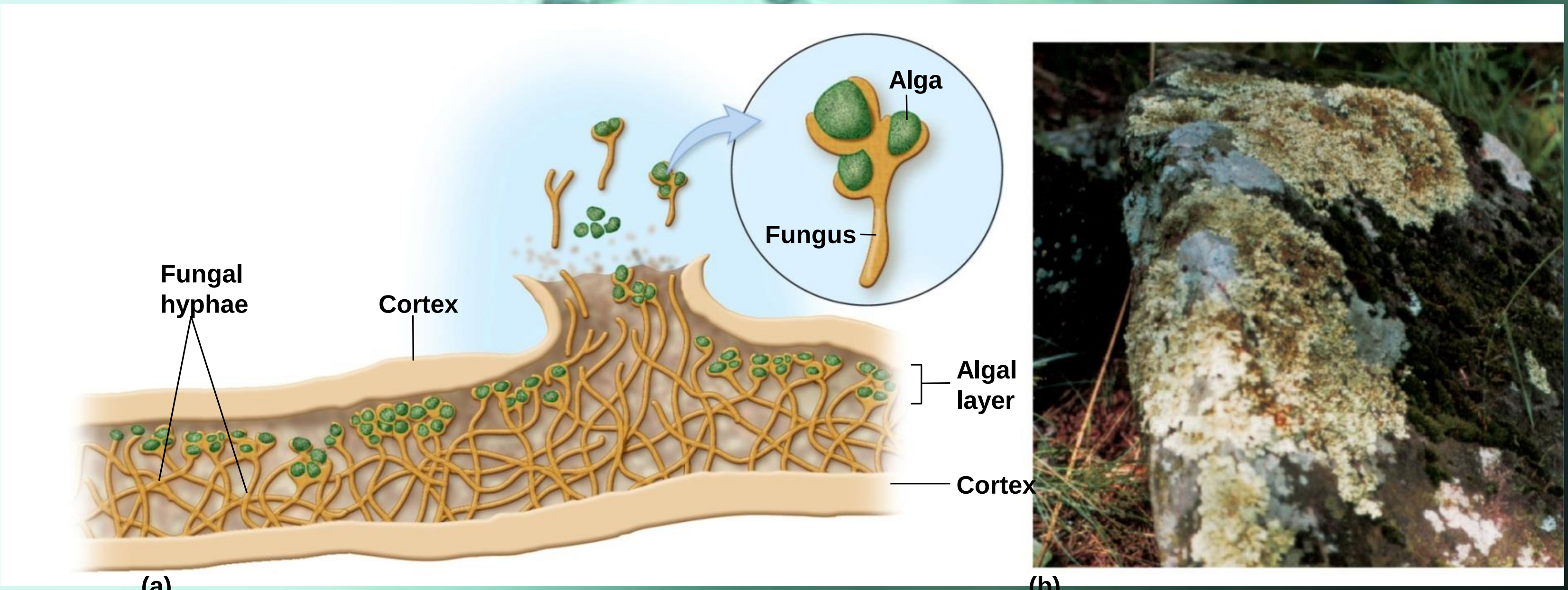
- Structure of Fungi (continued…)
  - Fungi most successful in moist environments
  - Some have specialized hyphae
    - Parasitic fungi: <u>haustoria</u> protrude into host cells
    - Saprophytic fungi: <u>rhizoids</u> may anchor to substrate
  - Dimorphic fungi can grow as single yeast cells or multicellular mycelia
    - E.g., *Histoplasma capsulatum* mold in soil
    - Reproductive spores easily airborne; develop into yeast form when inhaled, cause disease

12.1. Fungi

- Fungal Habitats: mostly terrestrial
  - Found in nearly every habitat on earth, including thermal pools, volcanic craters, high salt environments
  - Some widespread; others specialize on a single plant
  - Fungi found that can degrade leather, cork, hair, wax, ink, jet fuel, carpet, drywall, even some plastics
  - Often responsible for food spoilage since may grow in concentrations of salts, sugars, acids that kill most bacteria, including pH range from 2.2 to 9.6
  - Most prefer 20°C to 35°C but easily survive lower temperatures; some grow below freezing
  - Most aerobic; some yeasts facultative anaerobes
  - Some obligate anaerobes live in rumen of cows

12.1. Fungi

- Symbiotic Relationships
  - Lichens are association of fungus and photosynthesizer (alga or cyanobacterium)
    - Fungus protects, absorbs water and nutrients
    - Allows growth in ecosystems where neither could alone could survive, e.g., sub-Arctic tundra, bare rock



12.1. Fungi

- Symbiotic Relationships (continued…)
  - <u>Mychorrhizas</u>: beneficial association with plant roots
    - High surface area of hyphae supplies plant with water, minerals, nitrogen, phosphorous
    - Plant supplies fungi with organic compounds
    - Estimated 80% of vascular plants have mychorrhizas
    - Plants grow better with; some (e.g., orchids) require

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12.1. Fungi

- Symbiotic Relationships (continued…)
  - Certain insects depend on fungi
  - E.g., leaf-cutting ants farm fungal gardens
    - Ants cannot eat often poisonous tropical vegetation
    - Instead, chop plants into pieces, add mycelium
    - Fungi grow, digest plant material, produce reproductive structures eaten by ant

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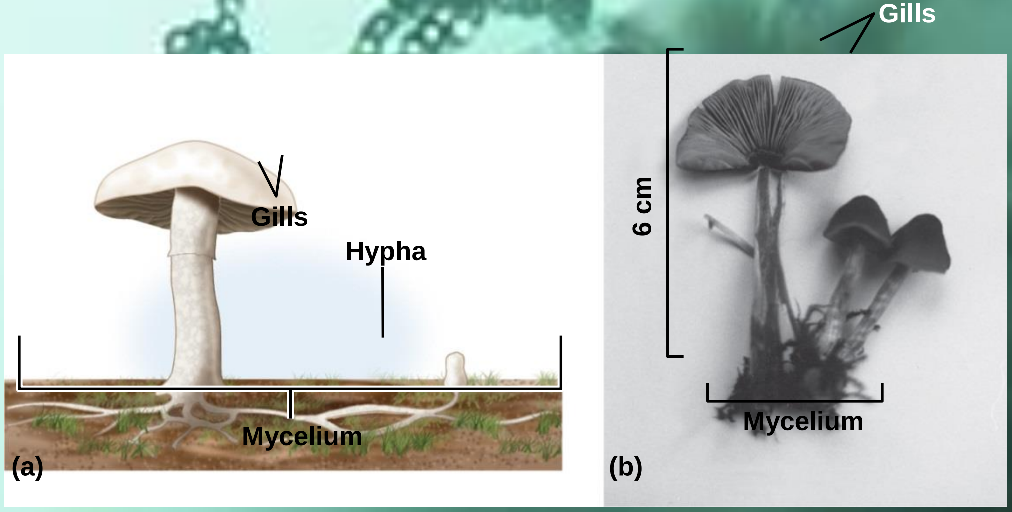
12.1. Fungi

- Reproduction in Fungi
  - Structures important in identification
  - Spore: reproductive cells formed sexually or asexually
    - Asexual spores called conidia (or sporangiospores in zygomycetes)
    - Housed in structures: sporangia (zygomycetes) or asci (ascomycetes) or in basidiomycetes beneath mushroom or puffball



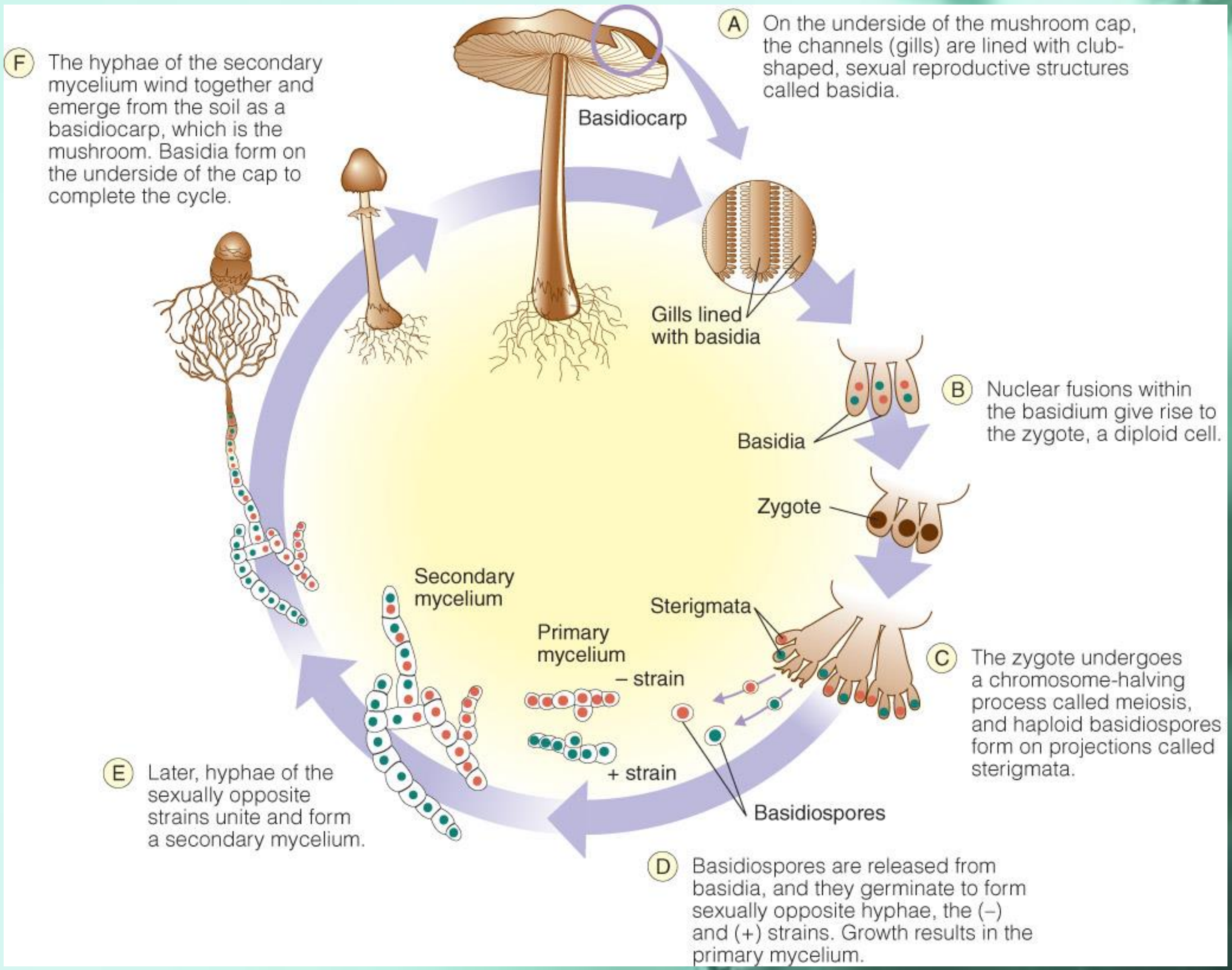
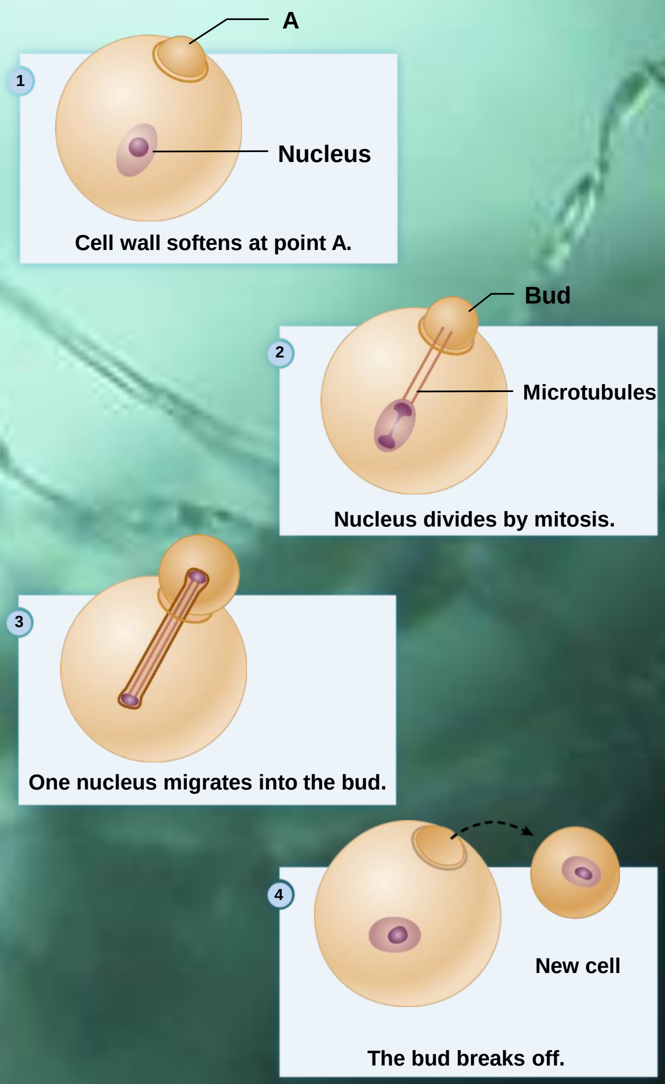


Figure 08.07: The Life Cycle of a Typical Basidiomycete.

12.1. Fungi

- Reproduction in Fungi (cont…)
  - Reproduction results from fusion of hyphae from two different mating types (termed +, –)
    - Yields dikaryon (two nuclei)
    - Nuclei fuse, undergo meiosis, form haploid spores
  - Yeast may reproduce by mitosis or <u>budding</u>
  - Molds may reproduce by fragmentation
  - Spores carried by wind, water
    - Germinate, grow hyphae



12.1. Fungi

- Economic Importance of Fungi
  - Antimicrobial medicines (e.g., penicillin, griseofulvin)
  - Useful tools for study of eukaryotic cells
  - Yeasts genetically engineered to produce important molecules including human insulin, hepatitis B vaccine
  - *Saccharomyces cerevisiae* (brewer's or baker's yeast) used in production of wine, beer, bread
  - Other species used in cheese making
  - Also greatest spoilers of food; tons of food discarded annually
  - Crop diseases impose billions of dollars in costs

12.1. Fungi

- Medical Importance of Fungi
  - Relatively few species infect humans, but many produce important antimicrobials; net impact likely positive
  - Some common (athlete's foot, jock itch); serious diseases rare (e.g., cryptococcal meningitis)
  - Human illnesses: 3 routes
    - Allergic reaction
    - Fungus grows on/in body; causes <u>mycosis</u> (disease)
    - Fungus produces toxins

TABLE 12.2 Some Medically Important Fungal Diseases

Disease	Causative Agent	Page for More Information
Candidial skin infection	*Candida albicans*	p. 545
Coccidioidomycosis	*Coccidioides immitis*	p. 514
Cryptococcal meningoencephalitis	*Cryptococcus neoformans*	p. 660
Histoplasmosis	*Histoplasma capsulatum*	p. 515
Pneumocystis pneumonia	*Pneumocystis jiroveci*	p. 708
Sporotrichosis	*Sporothrix schenckii*	p. 565
Vulvovaginal candidiasis	*Candida albicans*	p. 618
Tinea versicolor	*Malassezia furfur*	p. 544

12.1. Fungi

- Medical Importance of Fungi (continued...)
  - Fungal spores everywhere on earth, up to altitudes of more than 7 miles; air may contain >10,000 cells/m^3
  - Mycoses often named after causative agent (e.g., *Candida albicans* causes candidiasis)
  - May refer to affected body part (e.g., cutaneous mycoses of skin-invading molds called dermatophytes)
  - Toxins include aflatoxins produced by *Aspergillus* species; found in grains, peanuts; carcinogenic
  - Rye mold *Claviceps purpurea* (ergot) produces hallucinogenic toxin
    - Active chemical purified to yield drug ergotamine
  - Some (e.g., *Amanita*) produce toxins fatal to liver

12.2. Algae

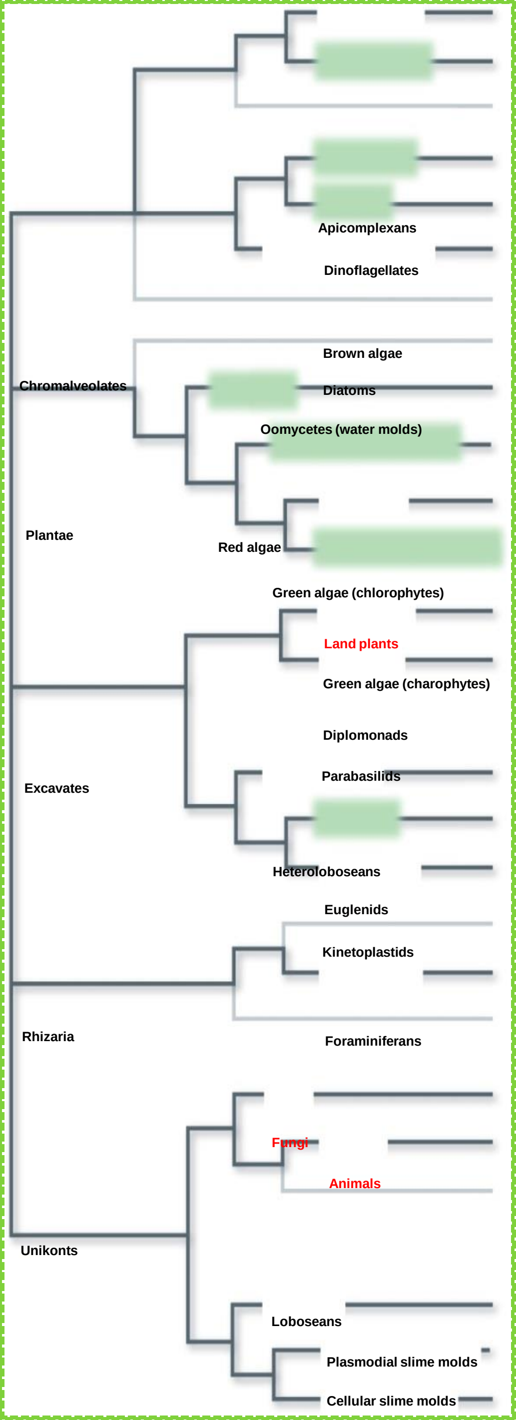
- Simple photosynthetic eukaryotes: protists
  - Differ from plants by lack of organized vascular system; simple reproductive structures

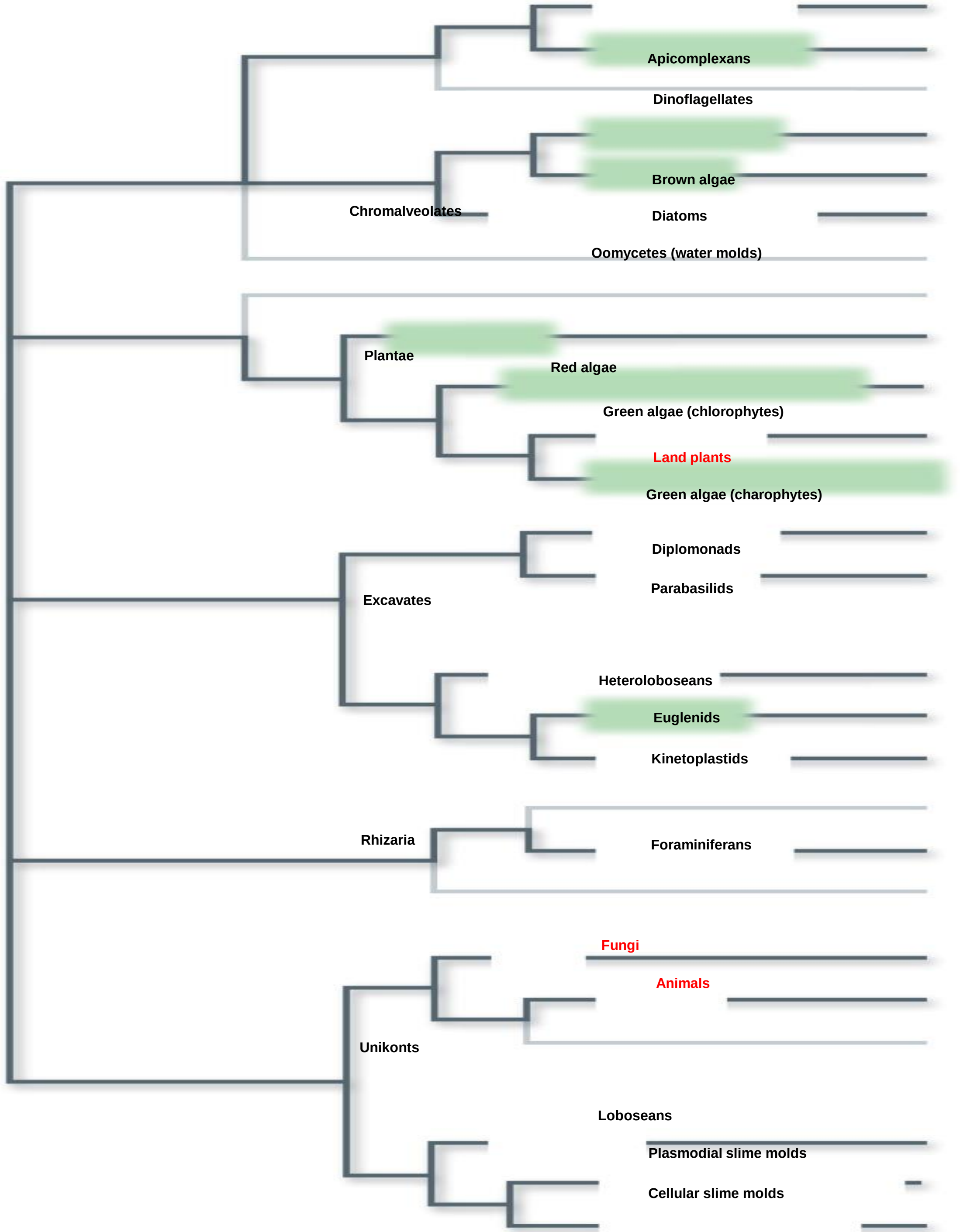
TABLE 12.3 Characteristics of Major Groups of Algae

Group	Usual Habitat	Principal Pigments (in addition to chlorophyll *a*)	Storage Product	Cell Wall	Mode of Reproduction
Green algae	Fresh water; salt water; soil; tree bark; lichens	Chlorophyll *b*; carotenes; xanthophylls	Starch	Cellulose and pectin	Asexual by multiple fission; spores or sexual
Brown algae	Salt water	Xanthophylls, especially fucoxanthin	Starchlike carbohydrates; mannitol; fats	Cellulose and pectin; alginic acid	Asexual, motile zoospores; sexual, motile gametes
Red algae, corallines	Mostly salt water, several genera in fresh water	Phycobilins; carotenes; xanthophylls	Starchlike carbohydrates	Cellulose and pectin; agar; carrageenan	Asexual spores; sexual gametes
Diatoms, golden brown algae	Fresh water; salt water; soil; higher plants	Carotenes	Starchlike carbohydrates	Pectin, often impregnated with silica or calcium	Asexual or sexual
Dinoflagellates	Mostly salt water but common in fresh water	Carotenes; xanthophylls	Starch; oils	Cellulose and pectin	Asexual; rarely sexual
Euglenids	Fresh water	Chlorophyll *b*; carotenes; xanthophylls	Fats; starchlike carbohydrates	Lacking, but elastic pellicle present	Asexual only by binary fission

12.2. Algae

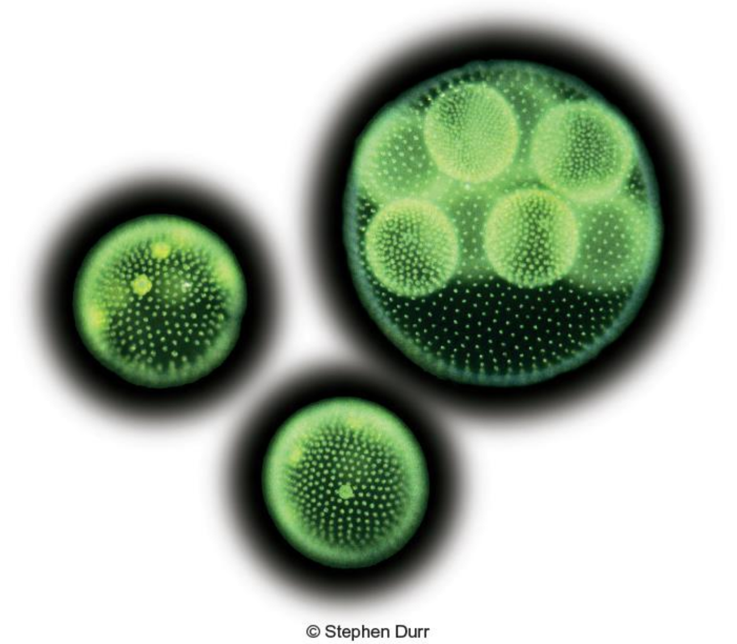
- Algae are diverse group of protists
  - Most are aquatic; other organisms depend upon them for food
  - Microscopic or macroscopic
  - Unicellular or multicellular
  - All contain chloroplasts and chlorophyll *a*; may contain other pigments
  - Rigid cell walls mostly cellulose
    - Red algae also have agar
    - Brown algae also have alginic acid
  - Not unified group; appear along evolutionary continuum based upon ribosomal RNA sequences




Apicomplexans
Dinoflagellates
Brown algae
Chromalveolates
Diatoms
Oomycetes (water molds)
Plantae
Red algae
Green algae (chlorophytes)
Land plants
Green algae (charophytes)
Diplomonads
Excavates
Parabasilids
Heteroloboseans
Euglenids
Kinetoplastids
Rhizaria
Foraminiferans
Fungi
Animals
Unikonts
Loboseans
Plasmodial slime molds
Cellular slime molds

12.2. Algae

- Microscopic Algae
  - Single cells propelled by flagella or free floating; or growth in long chains or filaments
  - Unicellular algae include diatoms, some green algae, dinoflagellates, euglenids, a few red algae
  - Some (e.g., *Volvox*) form colonies of 500 to 60,000 biflagellated cells
  - Diatoms incorporate silicon dioxide into cell walls; deposits mined for diatomaceous earth



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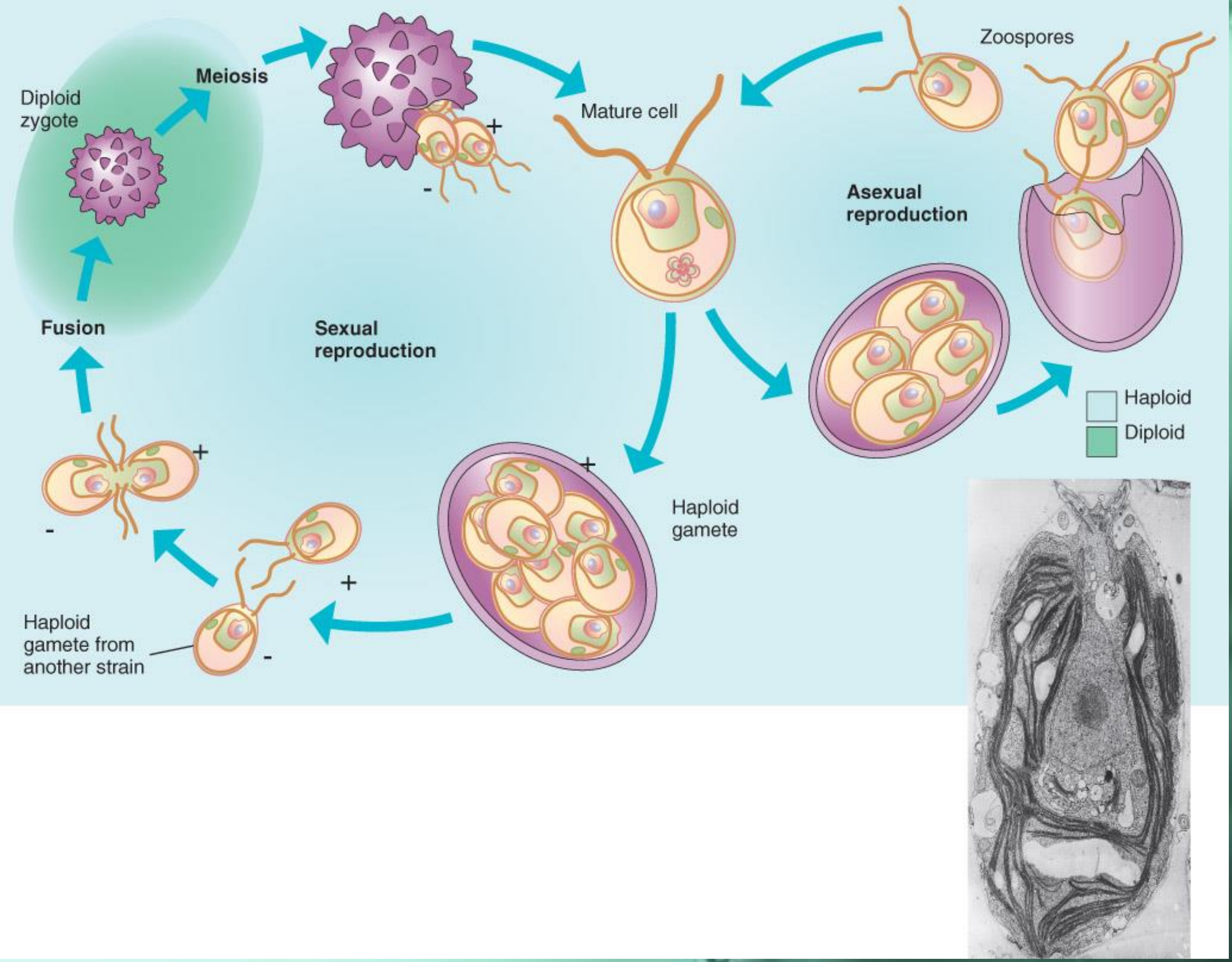
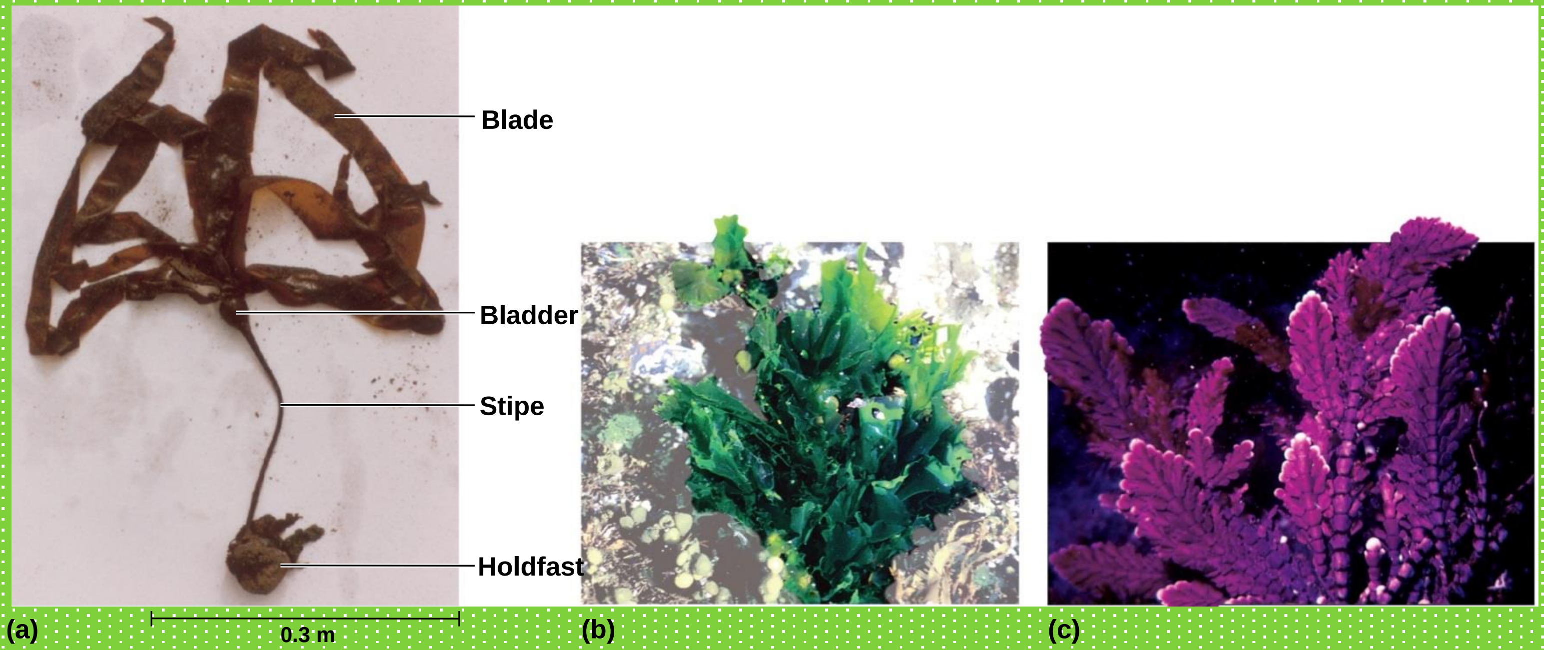


Figure 07.10: The Life Cycle of Chlamydomonas. This unicellular alga has both asexual and sexual aspects to its life cycle. Haploid and diploid forms are present at various points in the cycle.

12.2. Algae

- Macroscopic Algae
  - Multicellular brown algae, green algae, red algae
  - Some possess holdfast; strictly used for anchoring
  - Stalk (stipe) usually has attached leaflike structures
    - Termed blades; main site of photosynthesis



12.2. Algae

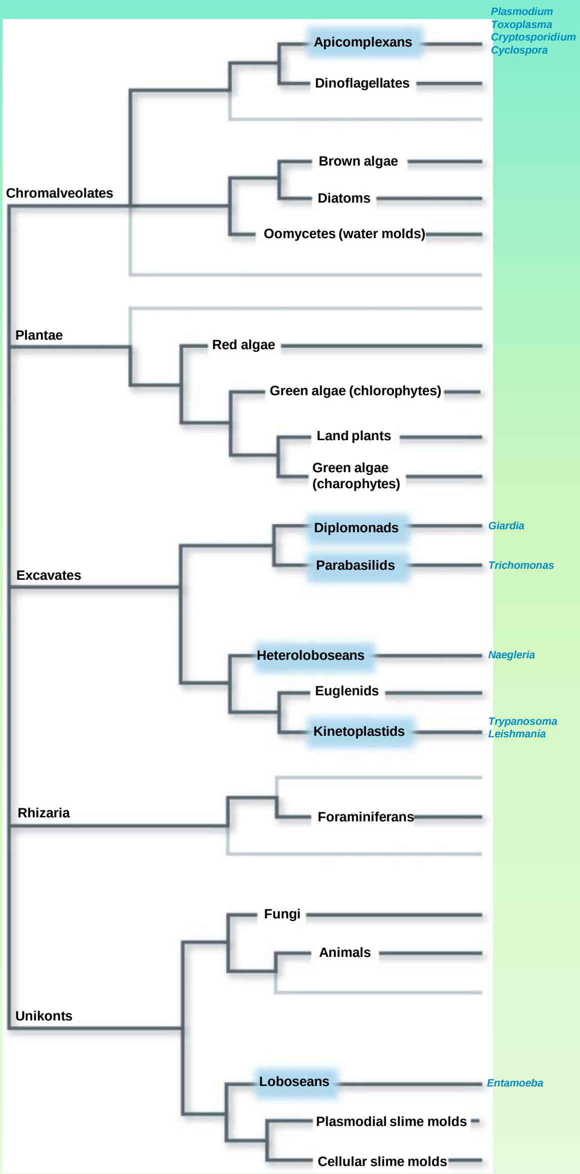
- Algal Habitats: fresh and salt water; moist soil
  - Major producers of O_2, consumers of CO_2
  - Algae with different pigments live at different depths
  - Plankton float near surface; unicellular algae comprise significant portion of phytoplankton
    - Form basis of food chain
    - Microscopic heterotrophs in zooplankton graze upon phytoplankton; both become food for other organisms
- Algal Reproduction: varied
  - Asexually by fragmentation
  - Alternation between haploid, diploid generation
    - Generations may look similar or different

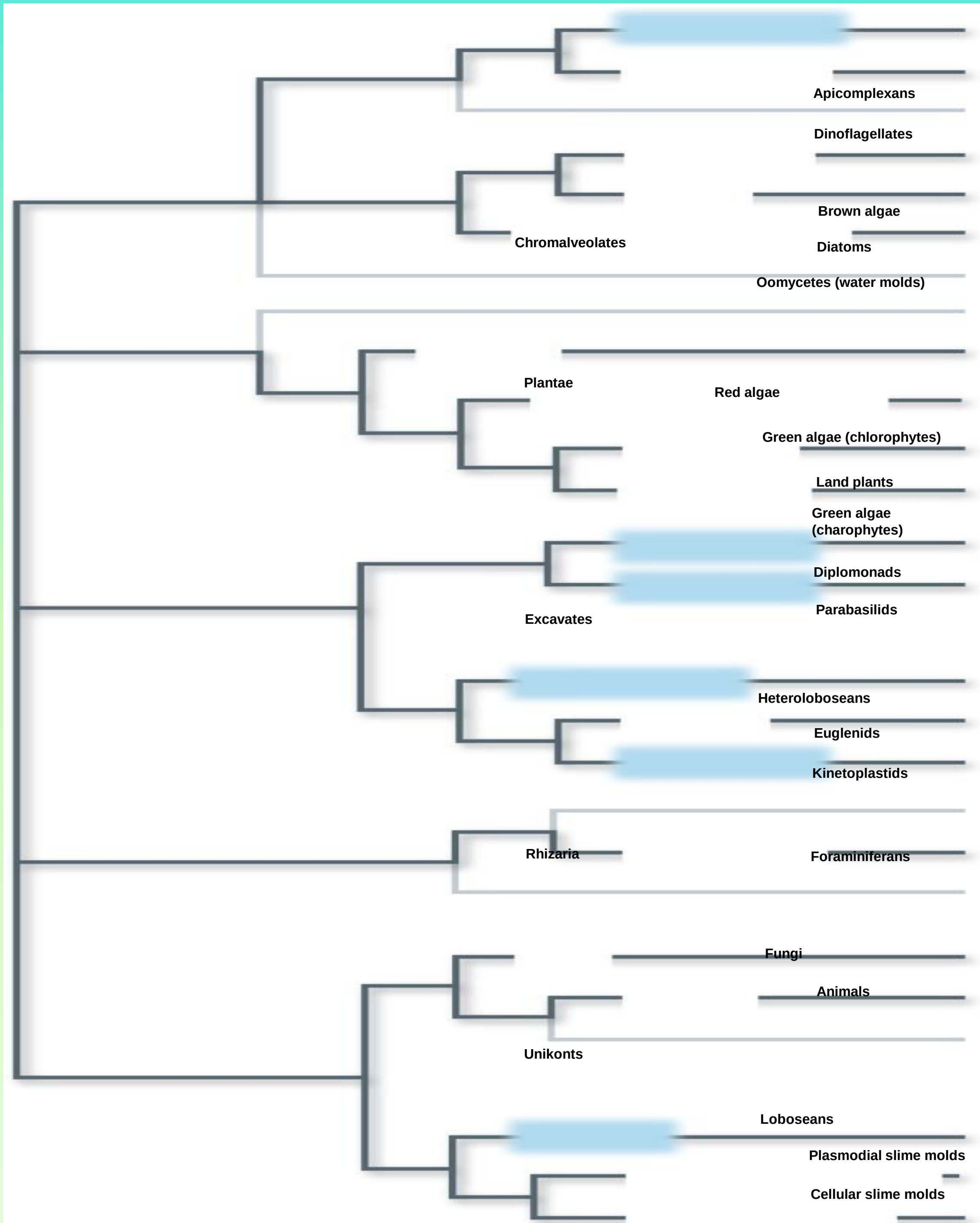
12.2. Algae

- Medical Importance of Algae
  - Do not directly cause human disease
    - Indirectly via toxins
  - Algal blooms from upwelling of nutrients and warmer temperatures, fertilizer runoff, untreated sewage
    - Algal blooms of dinoflagellates: red tides
    - *Gonyaulax* produce neurotoxins saxitoxin and gonyautoxin, among most potent non-protein poisons known
    - Shellfish feed upon *Gonyaulax* without harm, accumulate neurotoxin in tissues
    - Humans consuming can suffer paralytic shellfish poisoning; cooking does not destroy

12.3. Protozoa

- Protozoa means "animal-like"
  - Has little meaning in terms of evolutionary relatedness
  - Unicellular heterotrophic organisms that are not fungi, slime molds, or water molds
  - Like algae, slime molds, and water molds, protozoa are protists
  - Not unified group; appear along evolutionary continuum based upon ribosomal RNA sequences
  - Historically classified primarily by means of locomotion; DNA sequences indicate otherwise





Plasmodium
Toxoplasma
Cryptosporidium
Cyclospora

Giardia

Trichomonas

Naegleria

Trypanosoma
Leishmania

Entamoeba

12.3. Protozoa

- Types of Protozoa
  - Extreme diversity; some cause human diseases
  - Apicomplexans: parasites with apical complex at one end; helps penetrate membrane of host cells
    - Many have complex life cycles, alternate between sexual and asexual forms
    - Includes *Plasmodium*, causative agent of malaria, one of most significant diseases in world
    - Also *Toxoplasma gondii*, *Cryptosporidium parvum*, and *Cyclospora cayetanensis*

12.3. Protozoa

- Types of Protozoa (continued...)
  - Diplomonads and parabasalids: flagellated protists lacking mitochondria; reproduce asexually
  - Diplomonads typically have two nuclei
    - Reside in stagnant water low in O_2 or in anaerobic conditions inside hosts
    - *Giardia lamblia* causes diarrhea in campers
  - Parabasalids live within host (e.g., in termites; digest cellulose for host)
    - Others cause disease (e.g., *Trichomonas vaginalis*)
    - Hydrogenosome produces some ATP while generating hydrogen
    - A few parabasalids also reproduce sexually

12.3. Protozoa

- Types of Protozoa (continued...)
  - <u>Kinetoplastids</u>: have at least one flagellum
    - Distinctive complex mass of DNA in their large single mitochondrion
    - Mitochondrial DNA can produce variations in RNA that may allow rapid changes in cell surface molecules that enable evasion of immune system
    - *Leishmania major* (leishmaniasis, disease transmitted by sand flies)
    - *Trypanosoma cruzi* (Chagas' disease, which kills up to 50,000 people/year worldwide)
    - *Trypanosoma brucei* (African sleeping sickness)

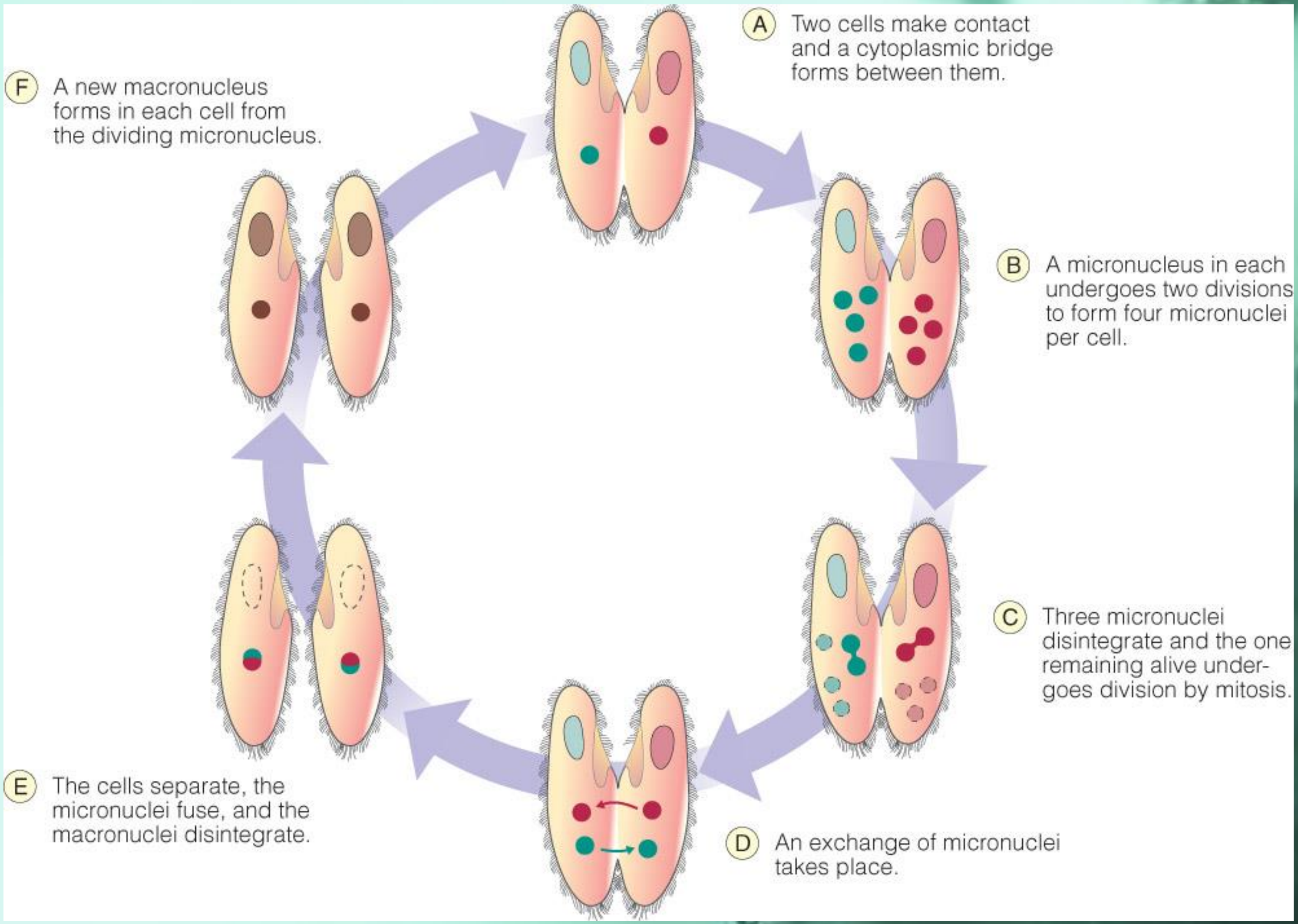


Figure 07.07: Sexual Recombination in Paramecium.

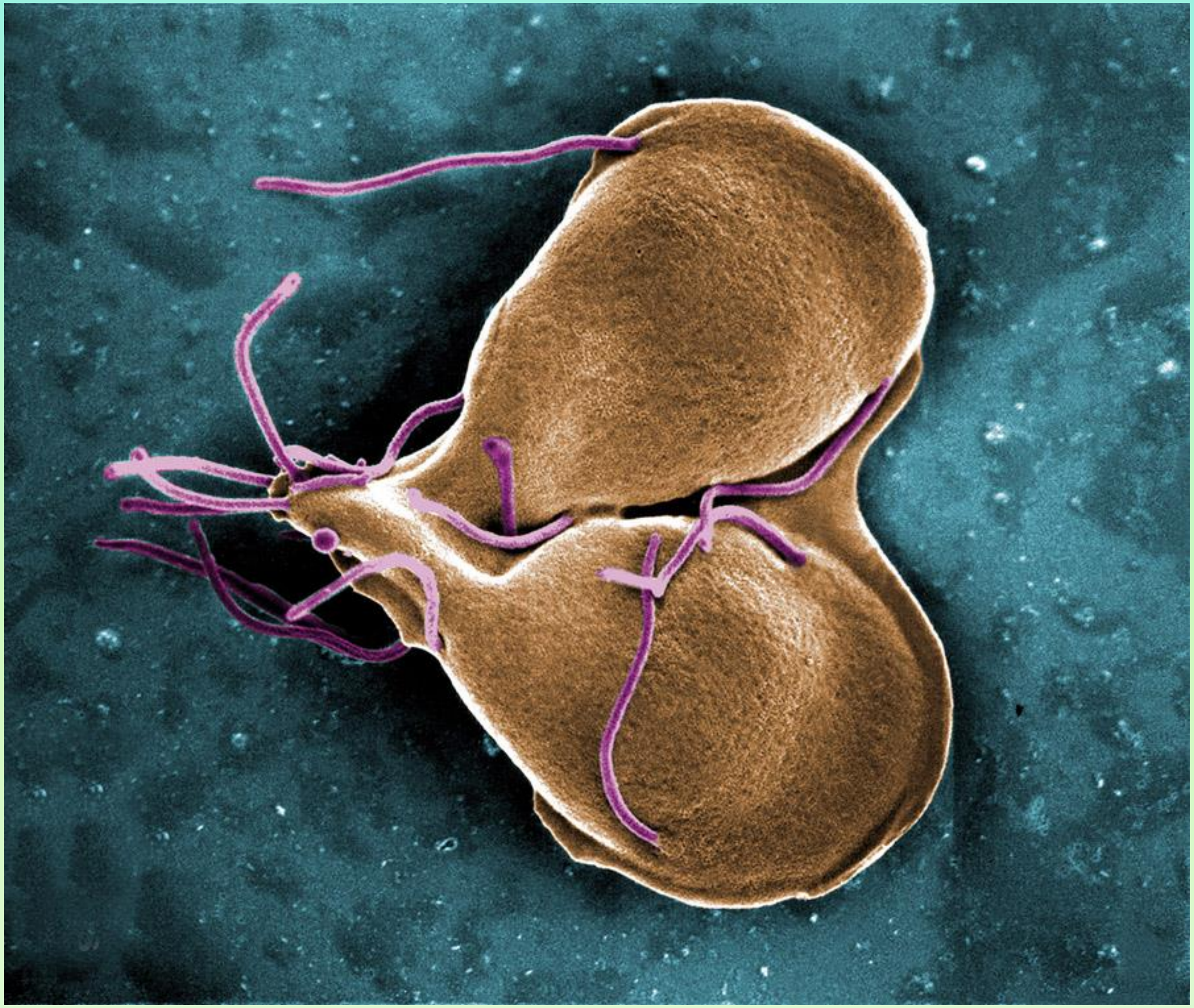
12.3. Protozoa

- Types of Protozoa (continued…)
  - <u>Loboseans and heteroloboseans</u>: ameboid (flexible) body form, but only distantly related to one another
  - Loboseans extend, retract pseudopodia
    - Engulf food particles by phagocytosis
    - *Entamoeba histolytica* causes diarrhea in humans
  - Heteroloboseans ameboid; also form flagellated cells
    - *Naegleria fowleri* swims in water; assumes ameboid form upon entering human body, eats host brain

(a) (b) (c)

Fig. 12.14

(a) (b) (c)



In 1674, Anton van Leeuwenhoek was the first to observe microbial life when he examined a drop of pond water through his microscope.

12.3. Protozoa

- Structure of Protozoa
  - No chloroplasts, cellulose cell wall, or chitin cell wall
  - Foraminifera secrete hard calcium shell; accumulate to form limestone deposits (e.g., White Cliffs of Dover)
  - Traditionally grouped by method of locomotion: cilia, flagella, pseudopodia
- Protozoan Habitats
  - Majority are free living aquatic organisms
  - Essential decomposers in many ecosystems
  - Some are parasitic
  - Zooplankton in marine environments
  - Abundant in soil, in or on plants and animals
  - Devour vast numbers of bacteria and algae

12.3. Protozoa

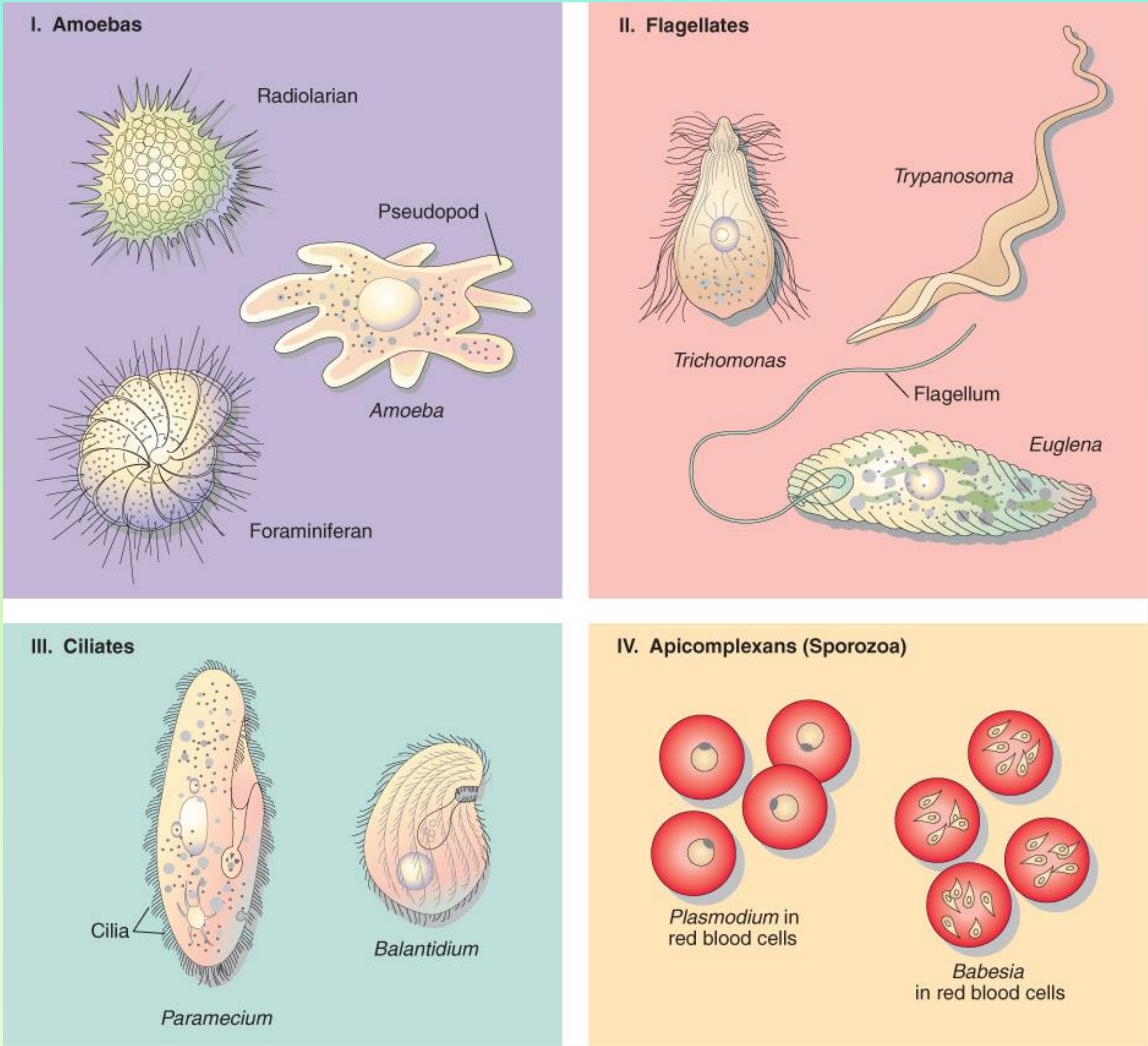
- Protozoan Reproduction
  - May have complex life cycles
    - More than one habitat or host
  - Polymorphic protozoan can exist as trophozoite (vegetative or feeding form) or cyst (resting form)
    - Environmental conditions can trigger cyst formation
    - Lack of nutrients, moisture, O_2, low T, chemicals
    - Some develop cell wall; helps protect during host transfer and from stomach acid (*Cryptosporidium*, *Entamoeba*)
    - Asexual, sexual reproduction common
    - Binary fission, also schizogony (multiple fission)

12.3. Protozoa

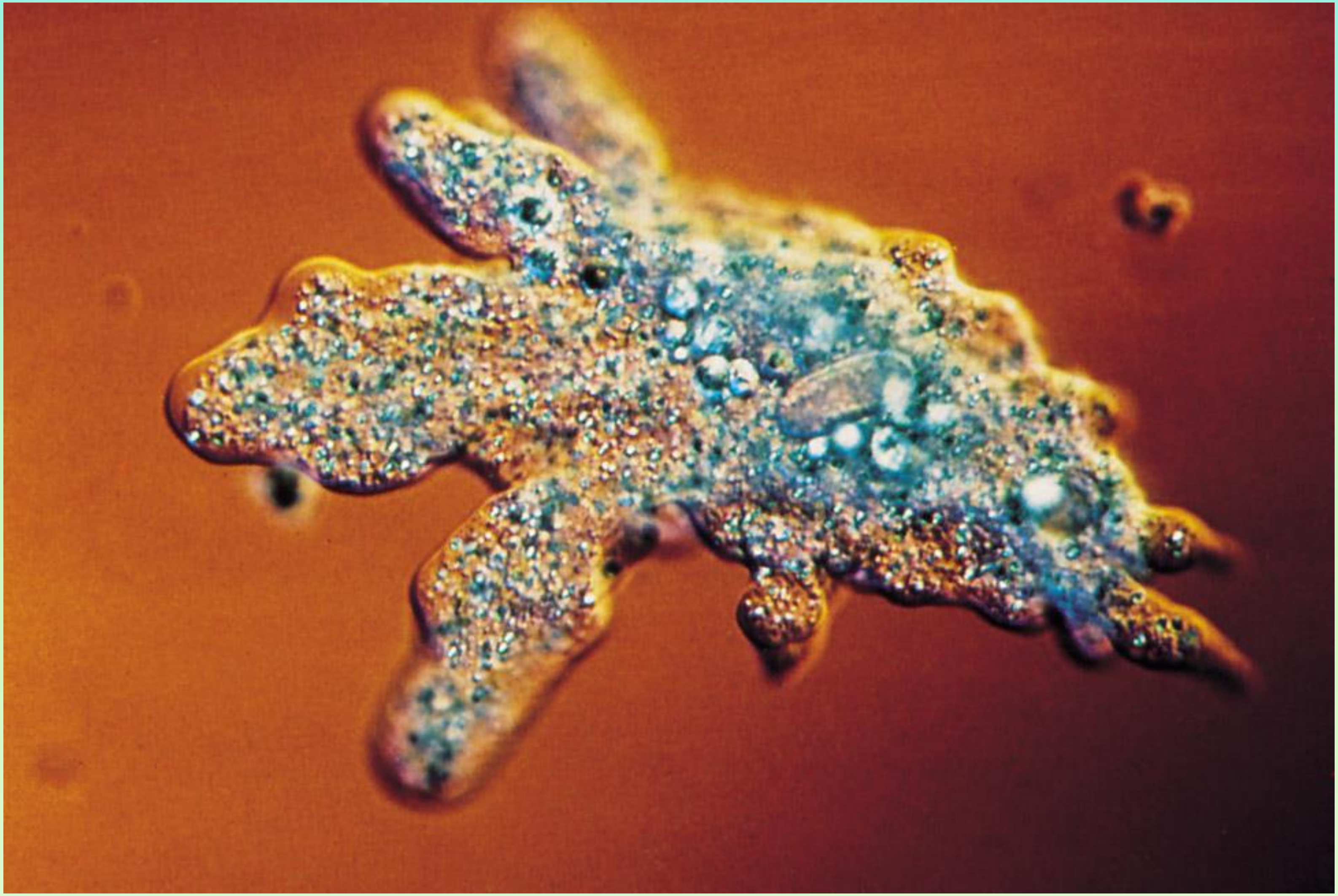
- Medical Importance of Protozoa
  - Majority do not cause disease, but protozoan pathogens have significant global health impact
  - ~300 million contract malaria each year; ~1 million die
  - Amebiasis (amebic dysentery) affects ~50 million/year, kills ~100,000
  - *Cryptosporidium, Giardia* among leading causes of diarrhea worldwide
  - Trypanosomes (sleeping sickness) have made some regions of Africa uninhabitable for centuries

TABLE 12.4 Protozoa of Medical Importance

rRNA Classification	Genus of Disease-Causing Protozoan	Disease Caused by Protozoan	Page for Additional Information
Apicomplexan	*Plasmodium*	Malaria	p. 686
	Toxoplasma	Toxoplasmosis	p. 709
	Cryptosporidium	Cryptosporidiosis	p. 603
	Cyclospora	Cyclosporiasis	p. 604
Diplomonad	*Giardia*	Giardiasis	p. 602
Parabasalian	*Trichomonas*	Trichomoniasis	p. 635
Kinetoplastid	*Trypanosoma*	African sleeping sickness	p. 662
Heterolobosean	*Naegleria*	Primary amebic meningoencephalitis	p. 663
Lobosean	*Entamoeba*	Amebiasis (diarrhea)	pp. 605, 663



The Protozoa



Amoeba proteus.

12.4. Slime Molds and Water Molds

- Protists that were once considered types of fungi
  - May look, act like fungi, but at cellular and molecular levels are completely unrelated
  - Fungi and water molds are good examples of convergent evolution: independent development of similar characteristics
  - Slime molds: organisms composed of ameboid cells; live on soil, leaf litter, decaying vegetation
    - Ingest organic matter by phagocytosis
    - Important link in food chain: ingest microorganisms, serve as food for larger predators
    - Two types: cellular and plasmodial

12.4. Slime Molds and Water Molds

- <u>Slime molds</u> (continued…)
  - <u>Cellular slime molds</u>
  - Vegetative form is single ameba-like cell
  - When food runs out, cells aggregate into <u>slug</u>
  - Some cells form <u>fruiting body</u>, others <u>spores</u>
  - *Dictyostelium discoideum* is model organism

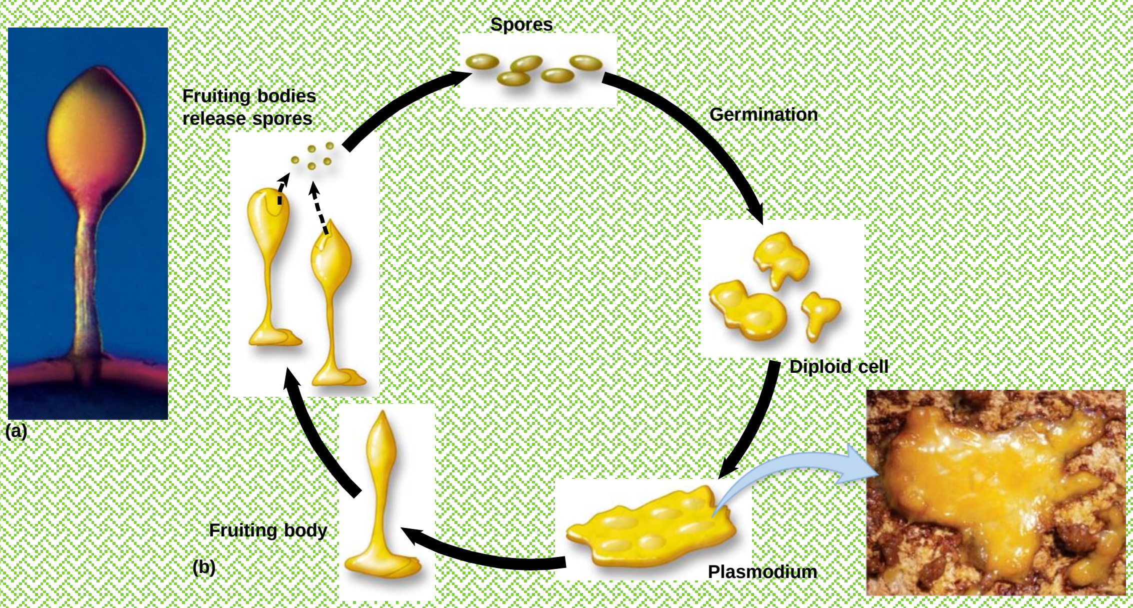
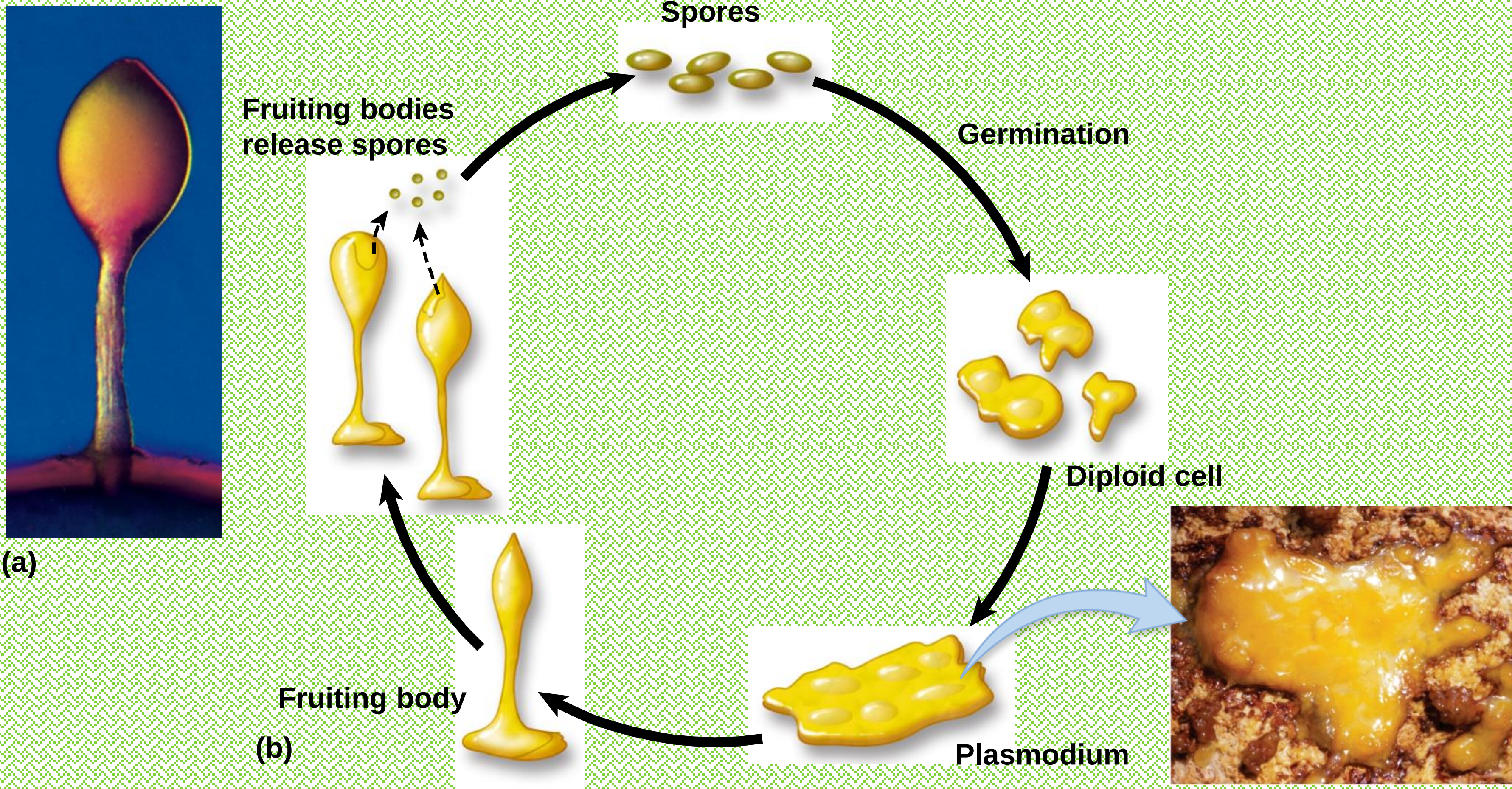


Fig. 12.15


Spores
Fruiting bodies
release spores
Germination
Diploid cell
Plasmodium
Fruiting body
(a)
(b)

12.4. Slime Molds and Water Molds

- Slime molds (continued...)
  - Plasmodial slime molds
  - Large multinucleated "super-amebas"
  - May reach 0.5 m diameter
  - Widespread, readily visible, often brightly colored
  - Following germination of haploid spores, cells fuse, form diploid cell; nucleus divides repeatedly to form multinucleated stage called plasmodium
  - Plasmodium oozes over decaying wood and leaves, ingests organic debris and microorganisms
  - Shortage of food, water stimulates formation of spore-bearing fruiting body

12.4. Slime Molds and Water Molds

- <u>Water molds: Oomycetes</u>
  - Form masses of white threads on decaying material
  - Secrete digestive enzymes onto substrate
  - Cytoplasm in filaments continuous with many nuclei
  - But cellulose in cell walls, not chitin
  - Lack chloroplasts; reproductive cells are flagellated
  - Important food crop diseases include downy mildew of grapes, potato blight

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12.5. Multicellular Parasites: Helminths

- Helminths include nematodes (roundworms), cestodes (tapeworms), trematodes (flukes)
  - Invade host tissue, rob host of nutrients
  - Largely controlled in industrialized nations; infect hundreds of millions in developing world
  - Varied routes of entry into human body
    - Hookworm larvae live in soil, burrow through skin
    - Multiply in digestive tract, excreted with feces
    - Poor sanitation, bare feet aid in transmission
    - ~740 million individuals infected
    - Nematode *Trichinella spiralis* ingested in animal flesh, especially undercooked pork
    - Pinworms (*Enterobius vermicularis*) ingested on food

12.5. Multicellular Parasites: Helminths

- Helminths (continued…)
  - Nematode *Wuchereria bancrofti* (elephantiasis) transmitted by mosquitoes; lodge in lymphatic vessels, block drainage
  - Nematode *Onchocerca volvulus* spread by flies (river blindness)
  - At least 18 million infected
  - ~270,000 completely blind; ~500,000 impaired
  - Results from inflammatory response to bacteria *Wolbachia pipientis* carried by nematode

CDC

12.5. Multicellular Parasites: Helminths

- Helminths (continued...)
  - May have complex life cycle with one or more intermediate hosts
  - Snails are intermediate host for fluke *Schistosoma mansoni* (schistosomiasis); reproduction takes place in humans, the definitive host
  - Humans may become dead-end host if infected by parasite that completes life cycle in another host
    - "Swimmer's itch" caused by flukes

12.5. Multicellular Parasites: Helminths

- Helminths (continued...)

TABLE 12.5 Nematodes, Cestodes, and Trematodes

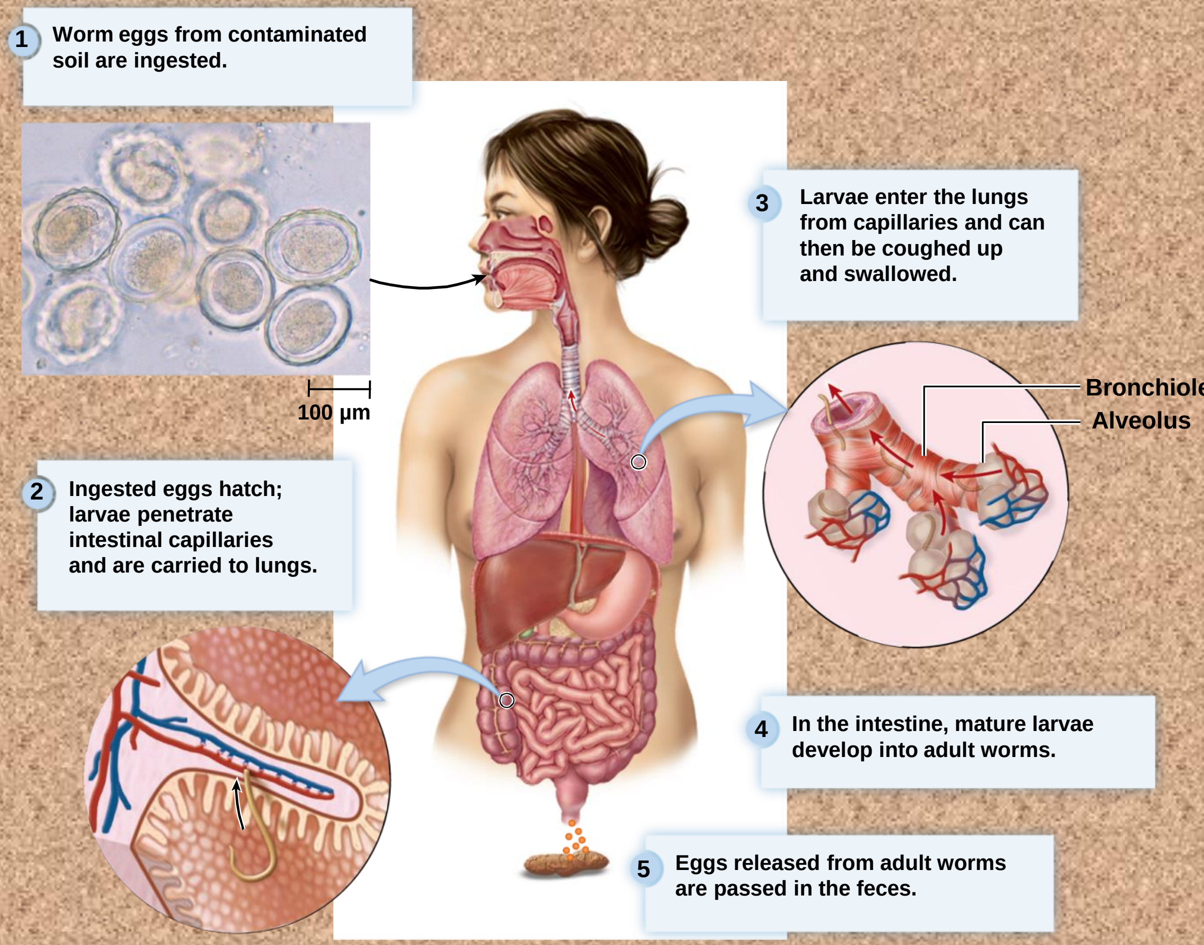
Infectious Agents	Disease	Disease Characteristics
Nematodes (roundworms)		
Pinworms (*Enterobius vermicularis*)	Enterobiasis	Anal itching, restlessness, irritability, nervousness, poor sleep
Whipworm (*Trichuris trichiura*)	Trichuriasis	Abdominal pain, bloody stools, weight loss
Hookworm (*Necator americanus* and *Ancylostoma duodenale*)	Hookworm disease	Anemia, weakness, fatigue, physical and intellectual disability in children
Threadworm (*Strongyloides stercoralis*)	Strongyloidiasis	Skin rash at site of penetration, cough, abdominal pains, weight loss
Ascaria (*Ascaris lumbricoides*)	Ascariasis	Abdominal pain, live worms vomited or passed in stools
Trichinella (*Trichinella spiralis*)	Trichinellosis	Fever, swelling of upper eyelids, muscle soreness
Filaria (*Wuchereria bancrofti* and *Brugia malayi*)	Filariasis	Fever, swelling of lymph glands, genitals, and extremities
Cestodes (tapeworms)		
Fish tapeworm (*Diphyllobothrium latum*)	Tapeworm disease	Few or no symptoms, sometimes anemia
Beef tapeworm (*Taenia saginata*)	Tapeworm disease	Few or no symptoms, sometimes anemia
Pork tapeworm (*Taenia solium*)	Cysticercosis	Variable symptoms depending on location and number of eggs that form larval cysts (cysticerci) in the body
Trematodes (flukes)		
Cercaria (*Schistosoma mansoni*)	Schistosomiasis	Liver damage, malnutrition, weakness, and accumulation of fluid in the abdominal cavity
Cercaria of birds and other animals	Swimmer's itch	Inflammation of the skin, itching

12.5. Multicellular Parasites: Helminths

- Helminths (continued...)
  - Roundworms (**nematodes**)
  - Cylindrical, tapered body
  - Digestive tract extends from mouth to anus
  - *Caenorhabditis elegans* is model eukaryotic organism
  - Many nematodes free-living in soil, water
  - Some are parasites
  - ~30,000 nematode species identified; may be >1 million
  - *Ascaris lumbricoides* causes ascariasis, most common roundworm disease
  - Females may reach 45 cm in length; release 200,000 eggs per day into intestinal tract

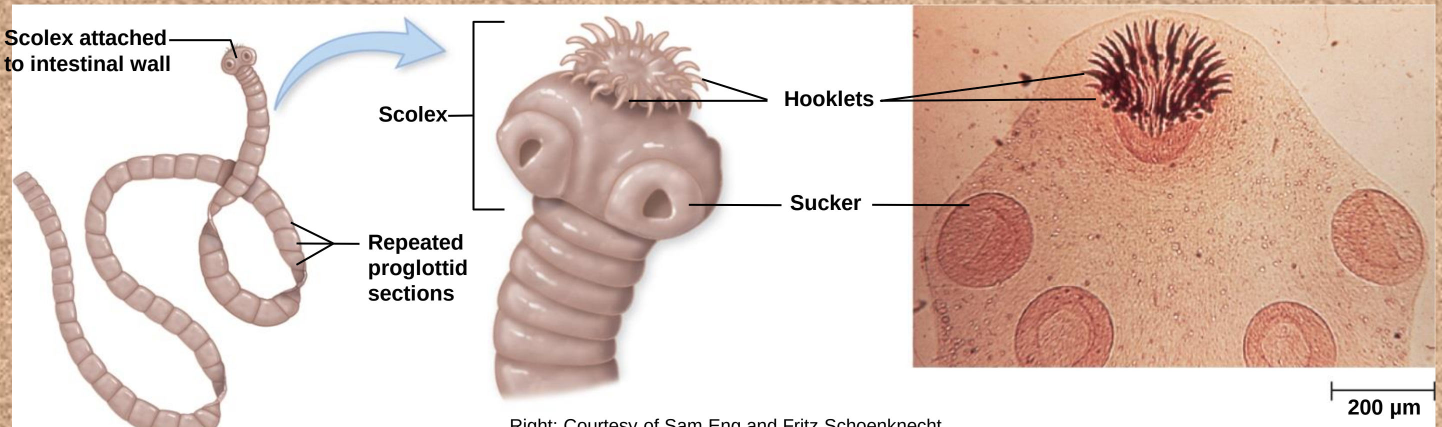
12.5. Multicellular Parasites: Helminths

- Roundworms (**nematodes**) (continued…)



12.5. Multicellular Parasites: Helminths

- Helminths (continued...)
  - Tapeworms (**cestodes**)
  - Flat, ribbon-shaped bodies; may exceed 1 m in length
  - No digestive system; absorb nutrients through body
  - Head end (scolex) attaches to intestines of host
  - Segments (proglottids) contain male, female structures
  - Proglottids farthest from scolex contain eggs; break off, eliminated in feces along with eggs



Right: Courtesy of Sam Eng and Fritz Schoenknecht

12.5. Multicellular Parasites: Helminths

- Helminths (continued…)
  - <u>Flukes (**trematodes**)</u>
  - Flat, leaf-shaped
  - Suckers hold in place while sucking fluids from host
  - Blood fluke *Schistosoma mansoni* most common cause of schistosomiasis, results in 20,000 deaths/year
  - Females lay eggs in blood vessels near intestine
  - Inflammatory reactions cause rupture of vessels; eggs released into intestines, excreted with feces
  - Larvae develop in water, taken up by species of snail
  - Following asexual reproduction, tail-bearing larvae released and can penetrate skin of human host wading in water, enter blood vessels

12.6. Arthropods

- Arthropods: insects and arachnids
  - Serve as vectors of transmission
  - Mechanical: transfer pathogen from one surface to another
  - Biological: essential part of life cycle (e.g., *Plasmodium* in *Anopheles* mosquito; trypanosomes in tsetse fly)
  - Animals may act as reservoir (e.g., rats)
  - Incidence can be decreased by controlling vectors or hosts (e.g., plague in U.S. controlled by mostly eliminating rat populations carrying *Yersinia pestis*)

12.6. Arthropods

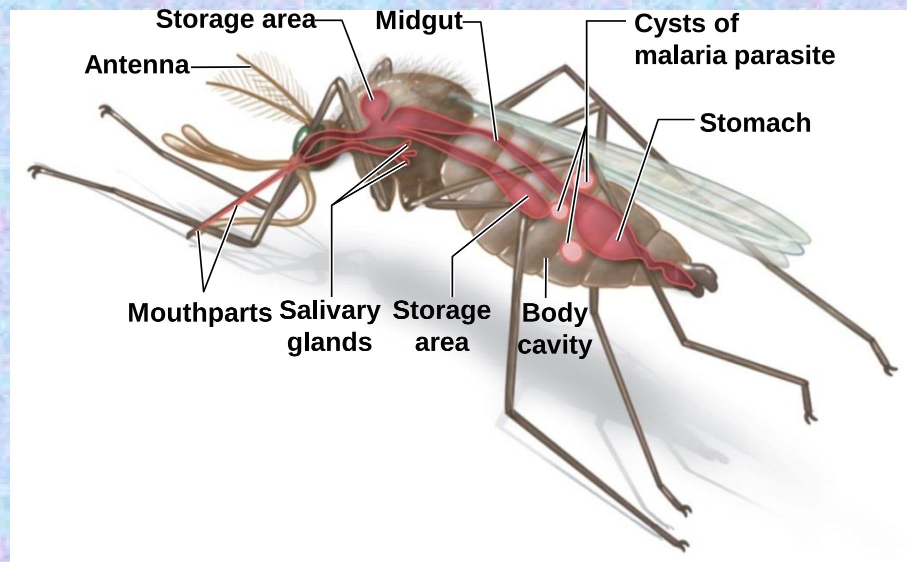
- Arthropods (continued…)

TABLE 12.6 Some Arthropods That Transmit Infectious Agents

Arthropod	Infectious Agent	Disease and Characteristic Features	Page for More Information
Insects			
Tsetse fly (*Glossina* species)	Trypanosomes	African sleeping sickness—sleepiness, headache, coma	p. 662
Sand fly (*Phlebotomus* species)	*Leishmania*	Leishmaniasis—ulcers, nosebleeds, diarrhea, fever, cough	p. 521
Black fly (*Simuliidae* species)	*Onchocercus*	Onchocerciasis—rash, itching, visual impairment	p. 296
Mosquito (*Anopheles* species)	*Plasmodium* species	Malaria—chills, bouts of recurring fever	p. 686
Mosquito (*Culex* species)	Togavirus	Equine encephalitis—fever, nausea, convulsions, coma	p. 655
Mosquito (*Aedes aegypti*)	Flavivirus	Yellow fever—fever, vomiting, jaundice, bleeding	p. 682
Mosquito (*Aedes aegypti*)	Flavivirus	Dengue fever—high fever; headache; joint, muscle, and bone pain	p. 683
Flea (*Xenopsylla cheopis*)	*Yersinia pestis*	Plague—fever, headache, confusion, enlarged lymph nodes, skin hemorrhage	p. 678
Louse (*Pediculus humanus*)	*Rickettsia prowazekii*	Typhus—fever, hemorrhage, rash, confusion	p. 521
Arachnids			
Tick (*Dermacentor* species)	*Rickettsia rickettsii*	Rocky Mountain spotted fever—fever, hemorrhagic rash, confusion	p. 529
Tick (*Ixodes* species)	*Borrelia burgdorferi*	Lyme disease—fever, rash, joint pain, nervous system impairment	p. 531

12.6. Arthropods

- Arthropods (continued...)
  - <u>Mosquitoes</u> insert feeding tube through host's skin
  - Ingest blood; can pick up infectious agents, transfer to subsequent hosts
  - Malaria, yellow fever, dengue fever, West Nile encephalitis transmitted by mosquitoes



12.6. Arthropods

- Arthropods (continued...)
  - Fleas are wingless insects, can jump up to 30 cm
  - Usually a nuisance but can transmit some pathogens
  - Causative agent of plague, *Yersinia pestis*
  - Fleas pick up when biting infected host; bacterium multiplies, blocks digestive tract
  - Starving fleas bite repeatedly, pass bacteria to host
  - Fleas can live in vacant buildings dormant for months
  - Mature quickly and jump to greet new hosts

12.6. Arthropods

- Arthropods (continued...)
  - Lice are small, wingless insects; suck blood through skin
  - Appendages adapted for attachment
  - *Pediculus humanus* easily spreads by direct contact or contact with personal items
  - Survives only a few days away from hosts
  - Body lice can transmit bacterial diseases: trench fever (*Bartonella quintana*); epidemic typhus (*Rickettsia prowazekii*); relapsing fever (*Borrelia recurrentis*)
  - Head lice do not transmit disease

CDC/Frank Collins, PhD

12.6. Arthropods

- Arthropods (continued…)
  - Ticks are arachnids (which lack wings and antennae; have four pairs of legs; have fused thorax and abdomen)
  - Live in low vegetation, wait for host passing by
  - Burrow into skin with mouthparts
  - May go unnoticed for days; feeds continually
  - Wood tick *Dermacentor andersoni* transmits Rocky Mountain spotted fever (bacterium *Rickettsia rickettsii*)
  - *Ixodes scapularis* transmits Lyme disease (bacterium *Borrelia burgdorferi*)
  - Saliva of some ticks can produce tick paralysis especially in children; recovery follows removal

The tick (Ixodes).

12.6. Arthropods

- Arthropods (continued...)
  - Mites are tiny, fast moving arachnids
  - Live on outer surfaces of plants, animals
  - Microscopic *Demodex* mites live unnoticed in hair follicles or oil-producing glands
  - Large numbers often live indoors, feed on shed skin cells
  - Do not transmit diseases but can trigger asthma
  - Chiggers (mite larvae) may attach, feed on fluids within skin cells, cause intense itching
  - *Sarcoptes scabiei* transmitted by personal contact, causes scabies