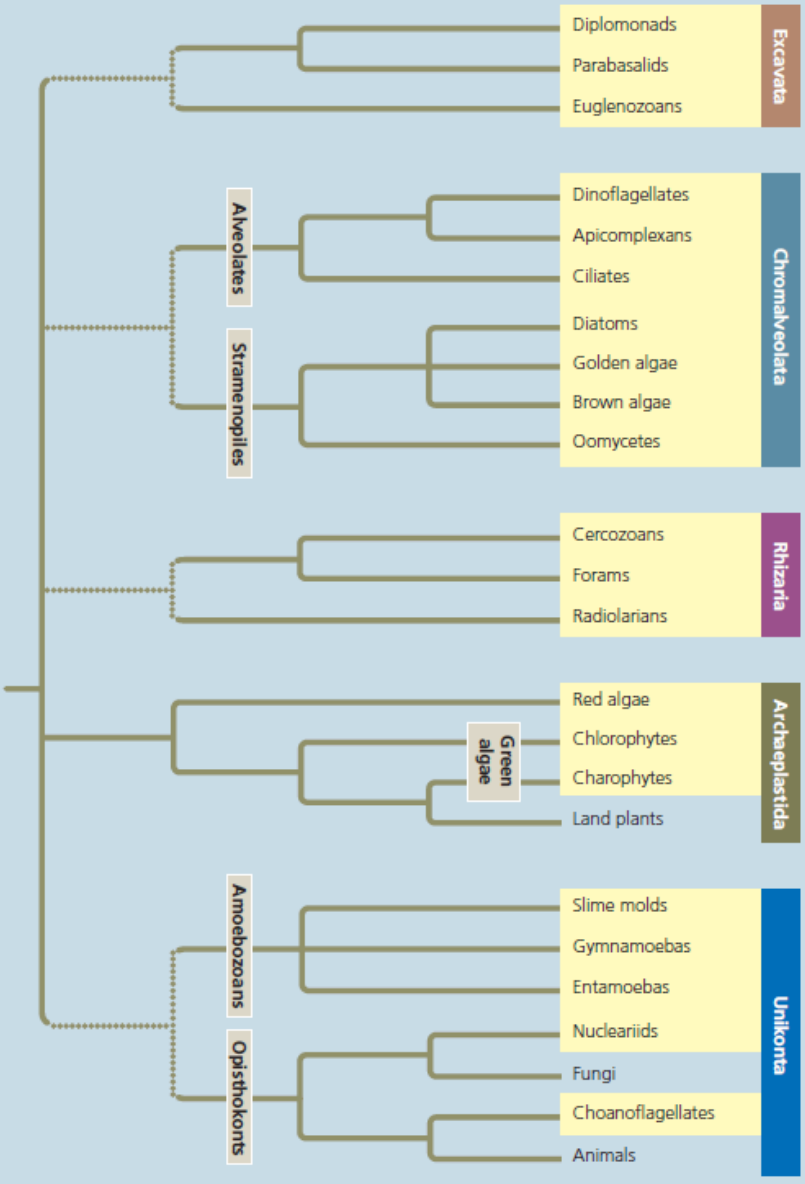
Cheat Sheet

The tree below represents a phylogenetic hypothesis for the relationships among all the eukaryotes on Earth today. The eukaryotic groups at the branch tips are related in larger "supergroups," labeled vertically at the far right of the tree. The kingdoms Plantae (land plants), Fungi, and Animalia (animals) have survived from the five-kingdom system of classification. Groups that were formerly classified in the kingdom Protista are listed in beige boxes. Dotted lines indicate evolutionary relationships that are uncertain and proposed clades that are under active debate.



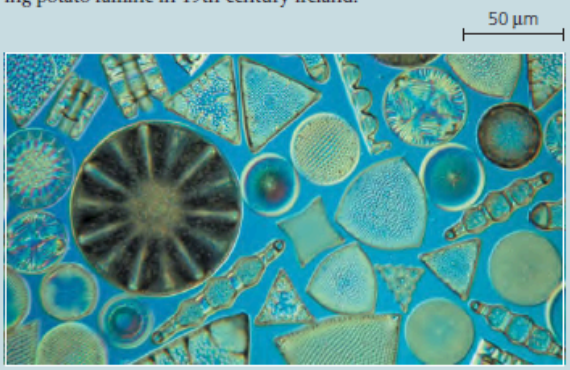
Excavata

Some members of this supergroup have an "excavated" groove on one side of the cell body. Two major clades (the parabasalids and diplomonads) have modified mitochondria; others (the euglenozoans) have flagella that differ in structure from those of other organisms. Excavates include parasites such as *Giardia*, as well as many predatory and photosynthetic species.

***Giardia intestinalis*, a diplomonad parasite.** This diplomonad (colorized SEM), which lacks the characteristic surface groove of the Excavata, can infect people when they drink water contaminated with feces containing *Giardia* cysts. Drinking such water—even from a seemingly pristine stream—can cause severe diarrhea. Boiling the water kills the parasite.

Chromalveolata

This group may have originated by an ancient secondary endosymbiosis event. Chromalveolates include some of the most important photosynthetic organisms on Earth, such as the diatoms shown here. The group also includes the brown algae that form underwater kelp "forests," as well as important pathogens, such as *Plasmodium*, which causes malaria, and *Phytophthora*, which caused the devastating potato famine in 19th-century Ireland.



Diatom diversity. These beautiful single-celled protists are important photosynthetic organisms in aquatic communities (LM).

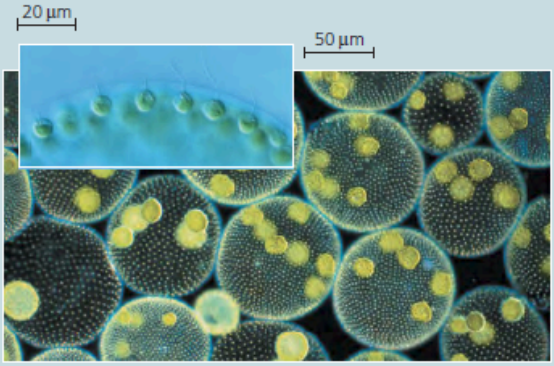
Rhizaria

This group contains many species of amoebas, most of which have pseudopodia that are threadlike in shape. Pseudopodia are extensions that can bulge from any portion of the cell; they are used in movement and in the capture of prey. Several recent molecular phylogenetic studies have suggested that Rhizaria should be nested within Chromalveolata; this hypothesis is currently being tested by other research groups.

***Globigerina*, a foram in the supergroup Rhizaria.** Threadlike pseudopodia extend through pores in the shell, or *test* (LM). The inset SEM shows a foram test, which is hardened by calcium carbonate.

Archaeplastida

This group of eukaryotes includes red algae and green algae, along with land plants (kingdom Plantae, discussed in Chapters 29 and 30). Red algae and green algae include unicellular species, colonial species (such as the green alga *Volvox*), and multicellular species. Many of the large algae known informally as "seaweeds" are multicellular red or green algae. Protists in Archaeplastida include key photosynthetic species that form the base of the food web in some aquatic communities.

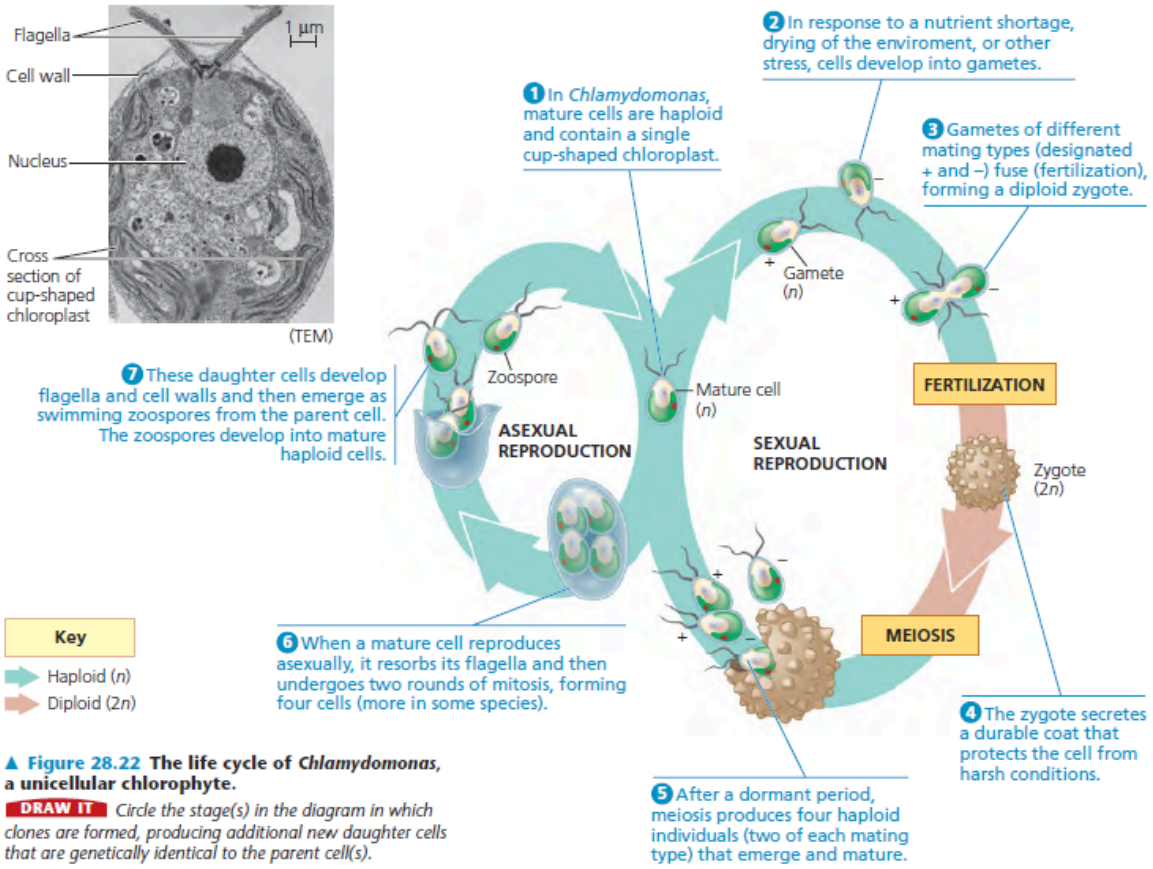


***Volvox*, a colonial freshwater green alga.** The colony is a hollow ball whose wall is composed of hundreds of biflagellated cells (see inset LM) embedded in a gelatinous matrix. The cells are usually connected by cytoplasmic strands; if isolated, these cells cannot reproduce. The large colonies seen here will eventually release the small "daughter" colonies within them (LM).

Unikonta

This group of eukaryotes includes amoebas that have lobe- or tube-shaped pseudopodia, as well as animals, fungi, and non-amoeba protists that are closely related to animals or fungi. According to one current hypothesis, the unikonts may have been the first group of eukaryotes to diverge from other eukaryotes (see Figure 28.23); however, this hypothesis has yet to be widely accepted.

A unikont amoeba. This amoeba (*Amoeba proteus*) is using its pseudopodia to move.

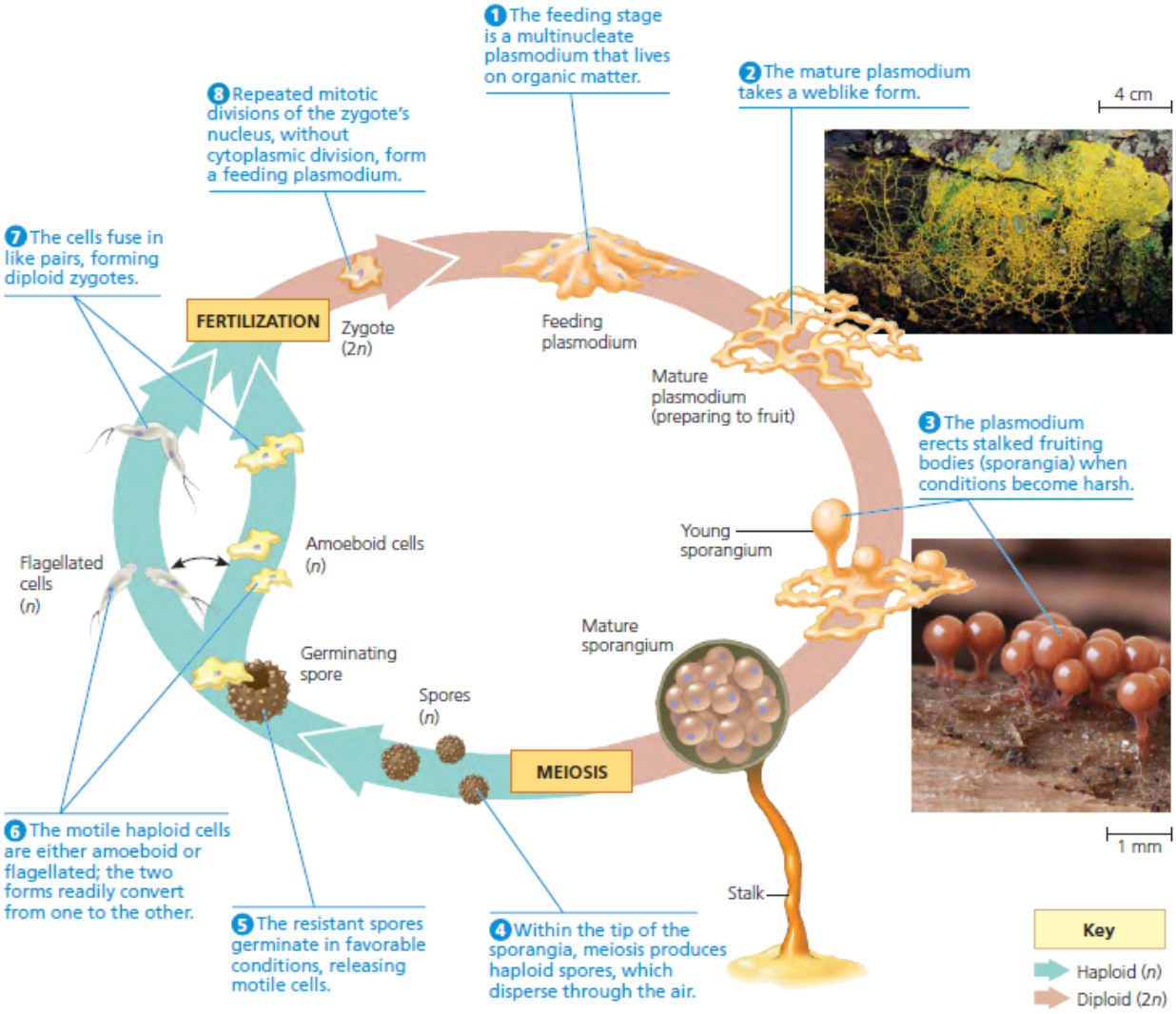


▲ Figure 28.22 The life cycle of *Chlamydomonas*, a unicellular chlorophyte.

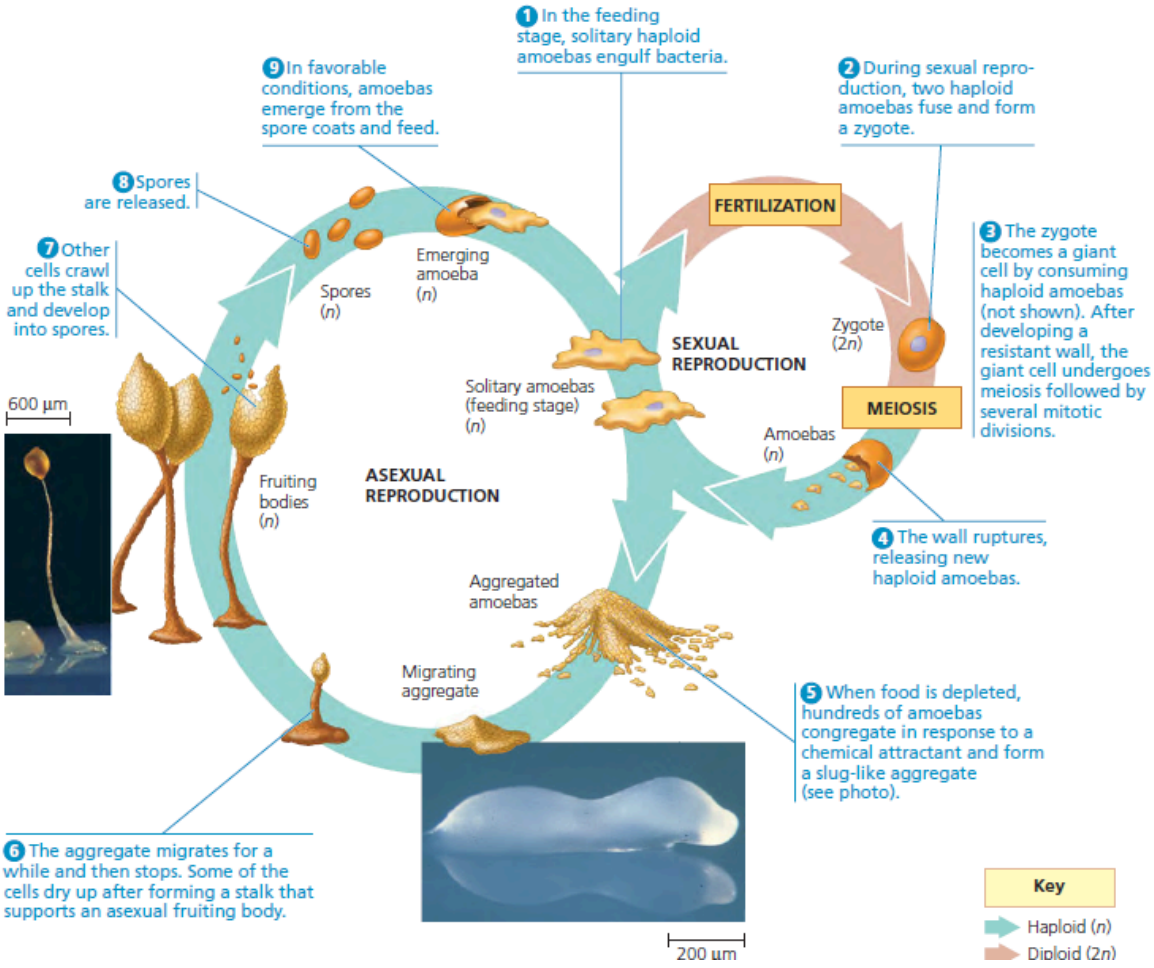
DRAW IT *Circle the stage(s) in the diagram in which clones are formed, producing additional new daughter cells that are genetically identical to the parent cell(s).*

their unique life cycles.

tends pseudopodia through moist soil, leaf mulch, or rotting



▲ **Figure 28.24 The life cycle of a plasmodial slime mold.**


1 In the feeding stage, solitary haploid amoebas engulf bacteria.
2 During sexual reproduction, two haploid amoebas fuse and form a zygote.
3 The zygote becomes a giant cell by consuming haploid amoebas (not shown). After developing a resistant wall, the giant cell undergoes meiosis followed by several mitotic divisions.
4 The wall ruptures, releasing new haploid amoebas.
5 When food is depleted, hundreds of amoebas congregate in response to a chemical attractant and form a slug-like aggregate (see photo).
6 The aggregate migrates for a while and then stops. Some of the cells dry up after forming a stalk that supports an asexual fruiting body.
7 Other cells crawl up the stalk and develop into spores.
8 Spores are released.
9 In favorable conditions, amoebas emerge from the spore coats and feed.
FERTILIZATION
SEXUAL REPRODUCTION
MEIOSIS
ASEXUAL REPRODUCTION
Zygote (2n)
Amoebas (n)
Solitary amoebas (feeding stage) (n)
Aggregated amoebas
Migrating aggregate
Emerging amoeba (n)
Spores (n)
Fruiting bodies (n)
600 µm
200 µm
Key
Haploid (n)
Diploid (2n)

Chapter 28 Questions

1. **What are protists?**
2. **What are mixotrophs?**
3. **What are amitochondriate protists?**
4. **What gave rise to the diversity of protists?**
5. **Describe the five supergroups in the domain Eukarya and draw the phylogenetic tree.**
6. **What causes malaria?**
7. **What is a test?**
8. **From what type of bacteria did mitochondria originate?**
9. **How many times did mitochondria evolve?**
10. **What is algae?**
11. **How did red and green algae undergo secondary endosymbiosis?**
12. **What is Excavata?**
13. **Which two groups of Excavata have highly reduced mitochondria and lack plastids?**
14. **Describe the mitochondria of diplomonads.**
15. **What are diplomonads?**
16. **Describe the mitochondria of parabasalids.**
17. **What is *Trichomonas vaginalis*?**
18. **What are euglenozoans?**
19. **What are kinetoplastids?**
20. **What is *Trypanosoma*?**
21. **What are euglenids?**
22. **What is *Euglena*?**
23. **What is SAR?**
24. **What are stramenopiles?**
25. **What are diatoms?**
26. **What is diatomaceous earth?**
27. **How do diatoms pump CO_2 to the ocean floor?**
28. **What are golden algae?**
29. **What are brown algae?**
30. **What specialized structures do some brown algae have that resemble those of plants?**
31. **What is *Laminaria*?**
32. **What is algin?**
33. **Describe the life cycle of *Laminaria*.**
34. **What do heteromorphic and isomorphic mean?**
35. **What are alveolates?**
36. **What are dinoflagellates?**
37. **What are apicomplexans?**

38. **Describe the life cycle of apicomplexans (e.g. *Plasmodium*).**
39. **Why is *Plasmodium* such a problem?**
40. **What are ciliates?**
41. **What are rhizarians?**
42. **What are radiolarians?**
43. **What are foraminiferans (forams)?**
44. **What are cercozoans?**
45. **What is Archaeplastida?**
46. **What are red algae?**
47. **What is *Porphyra*?**
48. **What are green algae?**
49. **What three mechanisms contributed to the evolution of larger size and greater complexity in green algae?**
50. **Describe the life cycle of *Chlamydomonas*.**
51. **What is Unikonta?**
52. **What are amoebozoans?**
53. **What are slime molds(alternate name)?**
54. **What are the two types of slime molds?**
55. **What is *Dictyostelium discoideum*?**
56. **What are tubulinids?**
57. **What are entamoebas?**
58. **What are opisthokonts?**
59. **How do termites digest wood?**
60. **What are *Pfiesteria shumwayae* and *Phytophthora ramorum*?**
61. **What is *Phytophthora infestans*?**

Chapter 28 Answers

1. Very small, mostly unicellular eukaryotes
2. organisms that combine photosynthesis and heterotrophic nutrition
3. Organisms without conventional mitochondria and fewer membrane-enclosed organelles than other protists, thought to be first lineage to have diverged from other eukaryotes but now found to have mitochondria (reduced ones)
4. endosymbiosis (one organism lives in the other)
5. See picture
6. The alveolate *Plasmodium*
7. the shell of a foram (a type of rhizarian)
8. an alpha proteobacterium
9. Once (all mitochondria are descended from one common ancestor)
10. photosynthetic protists
11. They were ingested in food vacuoles of heterotrophic eukaryotes and became endosymbionts. the protists called chlorarachniophytes likely evolved from this (engulfed cell has tiny vestigial nucleus called nucleomorph whose genes are still transcribed)
12. A clade that was originally proposed based on morphological studies of the cytoskeleton
13. Diplomonads and Parabasalids (most found in anaerobic environments)
14. Mitosomes - reduced mitochondria, lack functional electron transport chains, cannot use oxygen to extract energy from organic molecules, use anaerobic pathways
15. Many are parasites (e.g. *Giardia intestinalis*, inhabits intestines of mammals), have two equal-size nuclei and multiple flagella
16. Reduced mitochondria, called hydrogenosomes, generate some energy anaerobically (releases hydrogen gas as a by-product)
17. Sexually transmitted parasitic parabasalid, infects 5 million people each year, travels along mucus of human reproductive/urinary tracts using flagella/undulation of membrane. if acidity of vagina is disturbed, *T. vaginalis* can outcompete beneficial microorganisms there and infect vagina (can infect urethra of males, usually without symptoms). *T. vaginalis* can feed on vaginal lining, promoting infection
18. Organisms with a rod with either a spiral or crystalline structure inside each of their flagella
19. Euglenozoans with a single, large mitochondrion that contains an organized mass of DNa called a kinetoplast. Include protists that prey on prokaryotes and protists that parasitize other eukaryotes
20. Genus of kinetoplastids that infect humans and cause sleeping sickness (neurological disease that is fatal if not treated, infection occurs via bite of vector organism, the African tsetse fly). Also causes Chagas' disease (transmitted by bloodsucking insects and can lead to congestive heart failure. surface has millions of copies of single protein, if immune system recognizes protein, new generations switch to new surface protein)
21. Euglenozoans with pocket at one end from with one or two flagella emerge. Some are mixotrophs

22. Euglenid commonly found in pond water, has eyespot (pigmented organelle that functions as light shield), light detector (allow the protist to move toward light), and pellicle (protein bands beneath plasma membrane that provide strength/flexibility)
23. super group consisting of stramenopiles, alveolates, and rhizarians
24. Subgroup of SAR that includes some of most important photosynthetic organisms. Have flagellum with numerous fine, hair-like projections usually paired with smooth flagellum
25. Unicellular algae that have a unique glass-like wall made of silicon dioxide embedded in an organic matrix (consists of two parts that overlap like a shoe box and its lid, protects from crushing jaws of predators (can withstand 1.4 million kg/m^2), most abundant photosynthetic organisms in ocean and in lakes
26. Sediments with massive accumulations of fossilized diatom walls, mined to be used as filtering medium/other uses
27. When uneaten diatoms die (during blooms, many diatoms remain uneaten), their bodies sink to the ocean floor and their bodies take decades/centuries to be decomposed
28. Stramenopiles with yellow and brown carotenoids, typically biflagellated cells (both attached near one end of the cell), most are unicellular, many are part of plankton, all are photosynthetic, some are mixotrophic, many form protective cysts to survive environmental deterioration
29. Stramenopiles, largest and most complex algae, all are multicellular, most are marine, common along temperate coasts with cold water currents, are brown/olive due to carotenoids in plastids, lack true tissues and organs
30. Holdfast (anchors alga like roots), stipe (stem equivalent), blades (leaf equivalent)
31. “kombu” in Japanese, used in soups
32. Gel-forming substance found in the cell walls of brown algae, used to thicken foods
33. Diploid individual (sporophyte) produces zoospores (spores with flagella, haploid) that develop into haploid, multicellular gametophytes that produce gametes, the union of which produces a diploid zygote (heteromorphic)
34. Sporophytes and gametophytes are structurally different
    sporophytes and gametophytes look similar
35. Members of SAR have membrane-enclosed sacs (alveoli) just under plasma membrane, includes dinoflagellates, apicomplexans, and ciliates
36. Alveolates with cells reinforced by cellulose plates. 2 flagella are located in grooves of the armor, the organism spins as it moves, half are purely heterotrophic, others are parts of phytoplankton, many are mixotrophic. Blooms in dinoflagellates cause “red tide” (coastal waters appear brownish red or pink because of the presence of carotenoids, toxins in some dinoflagellates kill many fish and invertebrates)
37. Nearly all are parasites of animals, attack nearly all animal species, spread through host as tiny infectious cells called sporozoites. One end (apex) of sporozoite contains complex of organelles specialized for penetrating host cells and tissues. Retain modified plastid (apicoplast) likely of red algal origin
38. Most have both sexual and asexual stages, usually require two or more host species for completion
    Lives in both mosquitoes and humans, causes malaria

39. Causes malaria, carrier (*Anopheles* mosquito) and *Plasmodium* are resistant to insecticides/antibiotics, live mainly inside cells (hidden from immune system) and continually changes surface proteins
40. Alveolates that use cilia to move and feed, most are predators, have two types of nuclei (tiny micronuclei and large macronuclei), cell has one or more of each type, reproduce asexually by binary fission. Macronucleus control everyday functions
41. Subgroup of SAR, most are amoebas (protists that move and feed by means of pseudopodia, extensions that may bulge from almost anywhere on the cell surface, to move, anchors pseudopodia then cytoplasm flows into pseudopodia, are not monophyletic, rhizarian amoebas have threadlike pseudopodia), others are flagellated protists that feed using threadlike pseudopodia
42. Rhizarians with delicate, intricately symmetrical internal skeletons generally made of silica. Mostly marine, pseudopodia radiate from central body, reinforced by bundles of microtubules covered in thin layer of cytoplasm (skeletons accumulate as an ooze)
43. Rhizarians with tests (porous shells consisting of a single piece of organic material hardened with calcium carbonate). Pseudopodia extend through pores. Many derive nutrition from symbiotic bacteria living inside the test. Largest have tests several, centimeters in diameter
44. Rhizarian amoeboid and flagellated protists that feed using threadlike pseudopodia. Most are heterotrophs (parasites of eukaryotes or predators). Chlorarachniophytes are mixotrophic. *Paulinella chromatophora* is an autotroph
45. super group descended from protist that engulfed a cyanobacterium (plants, red algae, green algae)
46. Many are reddish due to photosynthetic pigment phycoerythrin, masks the green of chlorophyll. Those adapted to shallow water have less phycoerythrin. Some live as heterotrophic parasites on other red algae. Abundant in coastal waters of tropical oceans. Most are multicellular, do not have flagellated gametes
47. Japanese nori, red algae used to wrap sushi
48. Have grass-green chloroplasts, structure/pigment composition similar to those of plants, some say should be part of extended plant kingdom (Viridiplantae). Charophytes include algae most closely related to plants. chlorophytes includes many species that live in freshwater, simplest are unicellular organisms (e.g. *Chlamydomonas*), resemble gametes of more complex chlorophytes.
49. Formation of colonies
    Formation of true multicellular bodies by cell division/differentiation
    Repeated division of nuclei with no cytoplasmic division
50. unicellular chlorophyte, see picture
51. Supergroup of eukaryotes including animals, fungi, some protists
52. Species of amoebas with lobe- or tube-shaped pseudopodia, includes slime molds, tubulinids, and entamoebas
53. Mycetozoans, thought to be fungi because they produce fruiting bodies
54. Plasmodial slime molds - Most are brightly colored: yellow or orange. Form mass called plasmodium with single mass of cytoplasm with many nuclei. Plasmodium extends

pseudopodia to engulf food particles by phagocytosis. If habitat begins to dry up or no food is left, plasmodium stops growing and differentiates into fruiting bodies that function in sexual reproduction

Cellular slime molds - Feeding stage of organism consists of solitary cells that function individually. When food is depleted, cells form slug-like aggregate that functions as a unit, aggregated cells remain separate by plasma membrane, form asexual fruiting body See picture…

55. Cellular slime mold, model organism for studying multicellularity
56. Group of amoebozoans with lobe- or tube-shaped pseudopodia, most are heterotrophs, some feed on detritus, others are predators
57. Parasitic amoebozoans, infect all classes of vertebrate animals and some invertebrates. Humans host 6 species, only *E. histolytica* is pathogenic, causing amoebic dysentery and is spread via contaminated drinking water, food, or eating utensils
58. Group of eukaryotes including animals, fungi, and several groups of protists.
59. Wood-digesting protists in the gut
60. Dinoflagellate parasite that attaches to victims and eats their skin, causes massive fish kills

    Major new forest pathogen, causes sudden oak death (SOD)
61. Causes potato late blight, turns stalks and stems of potato plants into black slime