Diversity classification and nomenclature of cultivated plants, weeds, microbes, and insect-pests

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Background

Basics

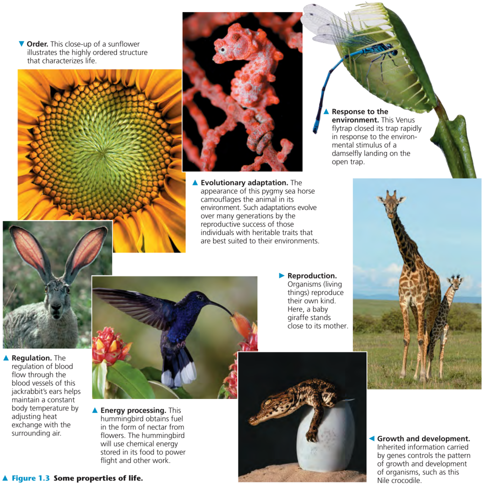


Figure 1: Some properties of life

Level of organisation

- Biosphere
- Ecosystems
- Communities
- Populations
- Organisms
- Organs and organ systems
- Tissues
- Cells
- Organelles
- Molecules

Systematics

- **Systematics** is a field of research which aims to organize the huge diversity of organisms.
- Objective is to use phylogenies that reflect natural relationships between organisms.
- Based on "relatedness"
- Who tests and verifies: Cytologists, geneticists, morphologist and evolutionary biologist.
- Traditionally morpho-anataomy was used to distinguish between organisms.
- In many cases, DNA sequences – so-called DNA barcodes can be used to identify species (see http://barcoding.si.edu).
- **Monographs** are works concerning whole groups of related species (e.g., monograph of the genus Primula), and **floras** are systematic works concerning the plant inventory of a geographical area (e.g., flora of Germany).
- Monographs and floras contain descriptions of the species involved and also, by means of a key, the tools for identifying a plant.

Relationships

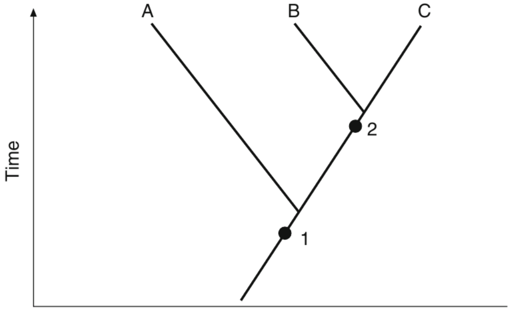


Figure 2: Relationships. The degree of relationship is defined by the relative age of the last common ancestor. Taxon B is more closely related to taxon C than to taxon A.

Characters

- Microscopic and macroscopic
- Morphology describes the external structure of plants and is very important in systematics.
- Anatomy is the study of internal plant structure. Includes: Histology, Cytology, Karyology, Palynology, Embryology
- The structure of plant compounds is dealt with in phytochemistry.
- A systematist can also draw on characters from physiology, ecology, chorology (the geographical distribution of taxa), and phytopathology and can also consider information on fossil forms taken from paleobotany.
- Experimental systematics, using breeding experiments and crossing success as a criterion for relationships, is not applied now. Instead, the analysis of proteins and nucleic acids has taken on special significance in phylogenetic research.

Taxonomic ranks

Taxonomic rank (English, Latin, abbreviation)	Typical ending	Taxonomic unit (examples, synonyms)
Kingdom (regnum)		Eukaryota
Subkingdom (subregnum)	-bionta	Chlorobionta
Phylum/division (phylum/division)	-phyta, -mycota	Streptophyta
Subphylum (subphylum)	-phytina, mycotina	Spermatophytina
Class (classis)	-phyceae, -mycetes, -opsida	Magnoliopsida
Subclass (subclassis)	-idea	–
Superorder (superordo)	-anae	–
Order (ordo)	-ales	Asterales
Family (familia)	-aceae	Asteraceae (= Compositae)
Subfamily (subfamilia)	-oideae	–
Tribe (tribus)	-eae	Anthemideae
Genus		*Achillea*
Section (sect.)		*Achillea* sect. *Achillea*
Series (ser.)		
Aggregate (agg.)		*Achillea millefolium* agg.
Species (spec., sp.)		*Achillea millefolium*
Subspecies (subspecies, subsp., ssp.)		*Achillea millefolium* subsp. *sudetica*
Variety (varietas, var.)		–
Form (forma, f.)		*Achillea millefolium* subsp. *sudetica* f. *rosea*

Figure 3: Overview of the more important taxonomic ranks, their standardized ending, and the taxonomic units using yarrow (Achillea millefolium L.) as an example

Classifying life

Approaches and trend

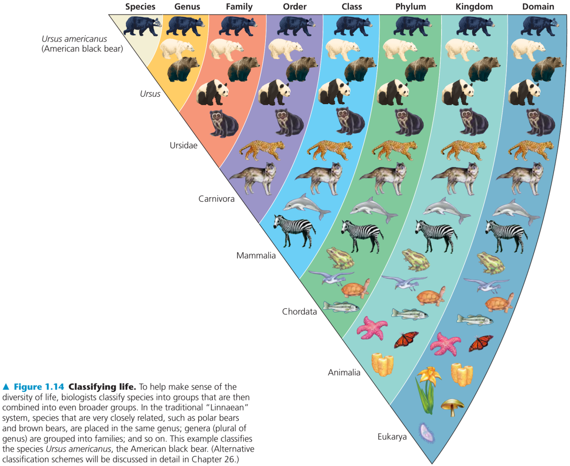


Figure 4: Linnaean classification of *Ursus americanus*

Approaches to classification

- The terms "plants" and "animals" were originally used to describe the main groups of living organisms (Regnum Plantae and Regnum Animale) defined by early systematics and taxonomy.
- Nowadays, it is well accepted that these groups reflect organizational levels with nutritional and physiological differences and are not natural groups. The term "plant kingdom" does not refer to an evolutionary unit with shared common ancestry and therefore does not refer to a taxon. Plants can be defined as photoautotrophic organisms.
- Ultrastructure of cell reveals two cell forms: Prokaryotic and eukaryotic
- Modern molecular phylogenetic methods indicate differentiation into three groups: the **Archaea**, **Bacteria** and **Eukarya**.

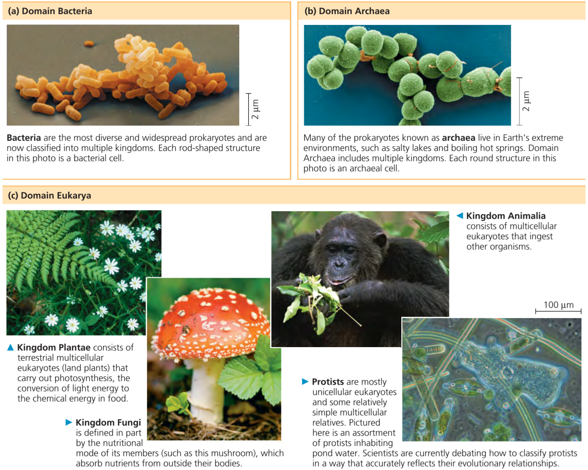


Figure 5: Three domains of life.

Domains of life

Classification

Bacteria phylums

- Primobacteriota: Deeply rooted
- Posibacteriota: Gram positive
- Negibacteriota: Gram negative
- Cyanobacteriota: Cyanoprokaryota, Cyanophyta, BGA

Archaea phylums

- Crenarchaeota
- Euryarchaeota

Eukarya subkingdoms

- Acrasiobionta
- Myxobionta
- Heterotrophic heterokontobionta
- Mycobionta
- Glaucobionta
- Rhodobionta
- Autotrophic heterokontobionta

Comparison of domains of life

Table 1: Comparison of some lower life forms

	Bacteria	Archaea	Eukarya
Nuclear envelope	Absent	Absent	Present
Membrane enclosed organelles	Absent	Absent	Present
Peptidoglycan in cell wall	Present	Absent	Absent
Membrane lipids	Unbranched hydrocarbons	Some branched hydrocarbons	Unbranched hydrocarbons
RNA polymerase	One kind	Several kinds	Several kinds
Initiator amino acid for protein synthesis	Formyl-methionine	Methionine	Methionine
Introns in genes	Very rare	Present in some genes	Present in many genes
Response to the antibiotics Streptomycin and chlormaphenicol	Growth inhibited	Growth not inhibited	Growth not inhibited
Histones associated with DNA	Absent	Present in some species	Present
Circular chromosome	Present	Present	Absent
Growth at temperatures greater than 100 degree C	No	Some species	No

Bacteria

Introduction

- Prokaryotic organisms having special chemical cell wall structure (murein sacculus).
- Eubacteria constitutes phyla other than Cyanobacteria.
- Mostly heterotrophic mode of nutrition.
- Average cell width: 1 μm, length: 3-10 μm
- May form colony or remain solitary
- Cell filaments, if present, can be branched or unbranched.
- DNA localized in nucleoid (coil-shaped structure)
- Gene maps have been plotted for several bacteria types (*E. coli*, *Salmonella typhimurium*).

Bacterial life

- Nutrition: The nutrition of bacteria differs according to the energy source, the electron donor, and the carbon source. Energy acquisition occurs either as a result of breakdown of substances in the substrate (chemotrophy) or by using light energy.
- Motility: Exhibit chemotaxis. Flagella may be present (single to multiple to scattered over entire surface)
- Reproduction and genetic matter exchange:
    - Binary fission
    - Endospore formation
    - Transformation
    - Transduction
    - Conjugation

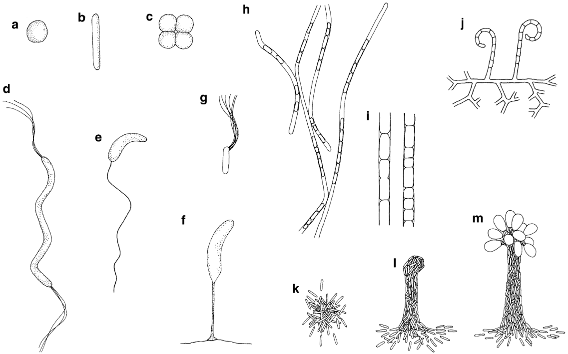


Figure 6: Bacterial forms. (a) Staphylococcus. (b) Lactobacillus. (c) Bdellovibrio. (d) Spirillum. (e) Caulobacter (x4,000). (f) Sarcina. (g–i) Sphaerotilus. (g) Motile stage (x700). (h) Sphaerotilus (x330). (i) Start of cell division (x800). (j) Streptomyces. (k–m) Chondromyces. (k) Rods (x200). (l) Sporocarps. (m) 'Fruit bodies' (x30)

Mode	Energy Source	Carbon Source	Types of Organisms
AUTOTROPH			
Photoautotroph	Light	CO_2, HCO_3^-, or related compound	Photosynthetic prokaryotes (for example, cyanobacteria); plants; certain protists (for example, algae)
Chemoautotroph	Inorganic chemicals (such as H_2S, NH_3, or Fe^{2+})	CO_2, HCO_3^-, or related compound	Unique to certain prokaryotes (for example, *Sulfolobus*)
HETEROTROPH			
Photoheterotroph	Light	Organic compounds	Unique to certain aquatic and salt-loving prokaryotes (for example, *Rhodobacter*, *Chloroflexus*)
Chemoheterotroph	Organic compounds	Organic compounds	Many prokaryotes (for example, *Clostridium*) and protists; fungi; animals; some plants

Figure 7: **Major nutritional modes of bacteria.**

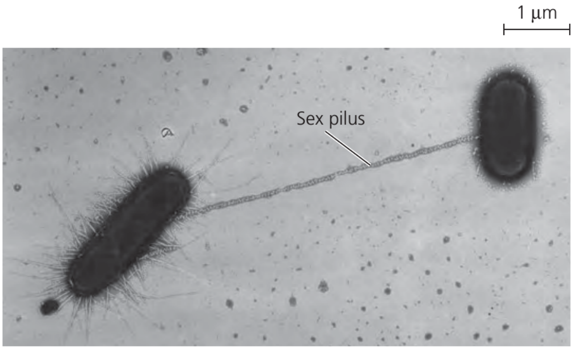


Figure 8: **Bacterial conjugation.**
The E. coli donor cell (left) extends a pilus that attaches to a recipient cell, a key first step in the transfer of DNA. The pilus is a flexible tube of protein subunits (TEM).

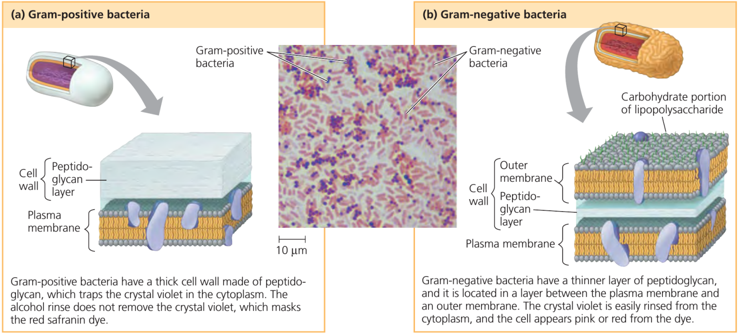


Figure 9: Gram staining

Major groups of bacteria

Proteobacteria

- Negibacteriota consists of 15 groups altogether.
- Proteobacteria are a group of gram negative bacteria.
- They are phototrophic, chemolithotrophic, or chemoorganotrophic.
- A genus of α-subgroup of this group, Bradyrhizobium, lives in symbiosis with soybean (in root nodules) and is capable of fixing atmospheric nitrogen.
- Both anaerobic and aerobic
- Recognized subgroups:
  - α Proteobacteria
  - β Proteobacteria
  - γ Proteobacteria
  - δ Proteobacteria
  - ϵ Proteobacteria

Subgroup: Alpha Proteobacteria

Many of the species in this subgroup are closely associated with eukaryotic hosts. For example, *Rhizobium* species live in nodules within the roots of legumes (plants of the pea/bean family), where the bacteria convert atmospheric N_2 to compounds the host plant can use to make proteins. Species in the genus *Agrobacterium* produce tumors in plants; genetic engineers use these bacteria to carry foreign DNA into the genomes of crop plants (see Figure 20.26). As explained in Chapter 25, scientists hypothesize that mitochondria evolved from aerobic alpha proteobacteria through endosymbiosis.

Rhizobium (arrows) inside a root cell of a legume (TEM)

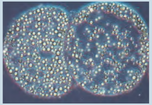
Subgroup: Beta Proteobacteria

This nutritionally diverse subgroup includes *Nitrosomonas*, a genus of soil bacteria that play an important role in nitrogen recycling by oxidizing ammonium (NH_4^+), producing nitrite (NO_2^-) as a waste product.

Nitrosomonas (colorized TEM)

Subgroup: Gamma Proteobacteria

This subgroup's autotrophic members include sulfur bacteria such as *Thiomargarita namibiensis* (see p. 557), which obtain energy by oxidizing H_2S, producing sulfur as a waste product (the small globules in the photograph at right). Some heterotrophic gamma proteobacteria are pathogens; for example, *Legionella* causes Legionnaires' disease, *Salmonella* is responsible for some cases of food poisoning, and *Vibrio cholerae* causes cholera. *Escherichia coli*, a common resident of the intestines of humans and other mammals, normally is not pathogenic.



Thiomargarita namibiensis containing sulfur wastes (LM)

Subgroup: Delta Proteobacteria

This subgroup includes the slime-secreting myxobacteria. When the soil dries out or food is scarce, the cells congregate into a fruiting body that releases resistant "myxospores." These cells found new colonies in favorable environments. Another group of delta proteobacteria, the bdellovibrios, attack other bacteria, charging at up to 100 µm/sec (comparable to a human running 240 km/hr). The attack begins when a bdellovibrio attaches to specific molecules found on the outer covering of some bacterial species. The bdellovibrio then drills into its prey by using digestive enzymes and spinning at 100 revolutions per second.

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

Subgroup: Epsilon Proteobacteria

Most species in this subgroup are pathogenic to humans or other animals. Epsilon proteobacteria include *Campylobacter*, which causes blood poisoning and intestinal inflammation, and *Helicobacter pylori*, which causes stomach ulcers.

Helicobacter pylori (colorized TEM)

Figure 10: Common bacteria in proteobacteria group

Chlamydias and spirochetes

- These parasites can survive only within animal cells, depending on their hosts for resources as basic as ATP.
- The gram-negative walls of chlamydias are unusual in that they lack peptidoglycan.
- One species, Chlamydia trachomatis, is the most common cause of blindness in the world and also causes nongonococcal urethritis, most common STD in US.
- These helical heterotrophs spiral through their environment by means of rotating, internal, flagellum-like filaments.
- Many spirochetes are free-living, but others are notorious pathogenic parasites: *Treponema pallidum* causes syphilis, and *Borrelia burgdorferi* causes Lyme disease.

Cyanobacteria

- Plantlike prokaryotes with oxygen-generating photosynthesis.
- Both solitary and filamentous cyanobacteria are abundant components of freshwater and marine phytoplankton, the collection of photosynthetic organisms that drift near the water's surface.
- Some filaments have cells specialized for nitrogen fixation, the process that incorporates atmospheric N_2 into inorganic compounds that can be used in the synthesis of amino acids and other organic molecules.

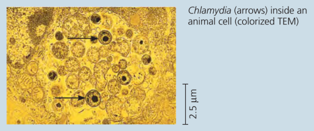


Figure 11: Chlamydias

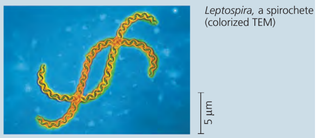


Figure 12: Spirochetes

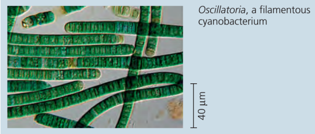


Figure 13: Cyanobacteria

Gram positive bacteria

- Highly diverse group
- Subgroups include:
    - Actinomycetes; form colonies or fee-living, Cause “earthy” order of soil
    - Cocci
    - Rods not forming spores
    - Spore forming rods
    - Coryneform
    - Mycoplasmas

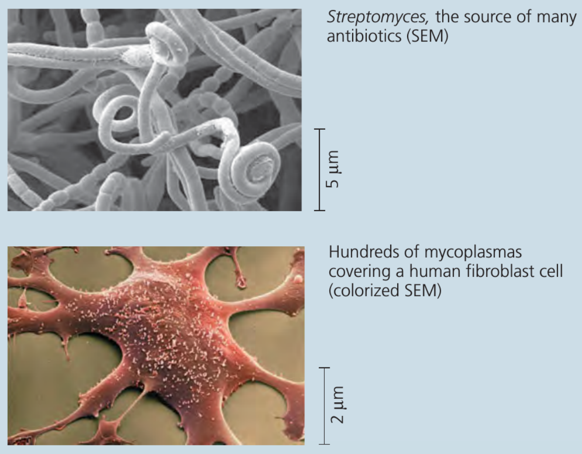


Figure 14: Gram positive bacteria

Archaea

- Archaea share certain traits with bacteria and other traits with eukaryotes.
- Includes **extremophiles**:
  - extreme halophiles: *Halobacterium* spp.
  - extreme thermophiles: *Pyrococcus furiosus*
- Includes methanogens (within guts of cattle, termites, in swamps)
- Euryarchaeota, Crenarchaeota, Korarchaeota, Nanoarchaeota (smallest known organism)

Eukarya

Acraciobionta

- Includes slime molds that lack flagellate cells.
- Pseudoplasmodia formed by the aggregation of single cells, without fusion.
- Cell walls are made of cellulose.

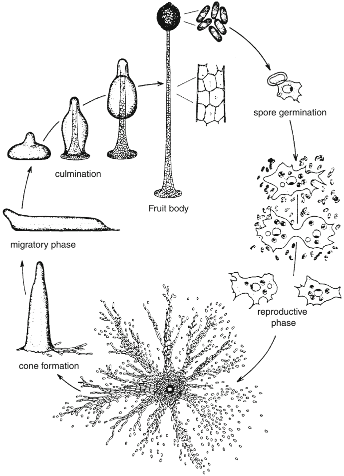


Figure 15: Life cycle of Dictyostelium discoideum (right x100, left x8 enlarged)

Myxobionta

- Fusion plasmodia arise as a result of fusion between myxoflagellates or myxamoeba, or they can develop from single cells without any previous sexual process.
- Contains phylum: Myxomycota, Plasmodiophoromycota

Figure 16: Plasmodium and sporocarps of *Badhamia utricularis*

Heterotrophic heterokontobionta

- Contains phylum: Labyrinthulmycota, Oomycota

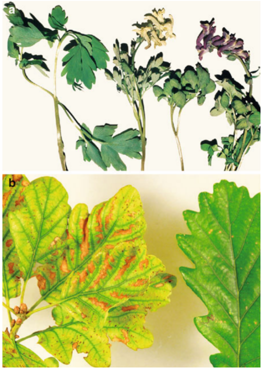


Figure 17: Oomycota, Peronosporales. (a) *Peronospora bulbocapni* on leaves of *Corydalis cava*; left, for comparison, an unaffected leaf. (b) Yellowing of oak leaves caused by root infections of *Phytophthora quercina*; right, normally colored leaf

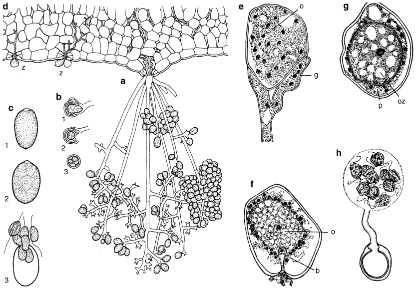


Figure 18: Oomycota, Peronosporales. (a–d) *Plasmopara viticola*. (a) Sporocystophore emerging from a stoma. (b) Oogonia (with a male gametangium) and zygotes (×100). (c) Formation and liberation of zoospores (×600). (d) Germination of the zoospores through the stomata penetrating the intercellular cavity (×250). (e) *Peronospora parasitica*, young multinuclear oogonium and male gametangium (×600). (f, g) *Albugo candida*. (f) Oogonium penetrated by the fertilization tube of a male gametangium which is donating the male nucleus (×600). (g) Zygote in the oogonium, surrounded by the young zygote wall and the periplasma (×600). (h) *Pythium ultimum*; zygotes germinating with zoospores (×800). b fertilization tube of the male gametangium, g male gametangium, p periplasma, o oogonium, oz central uninucleate part of the oogonium, z zoospore, 1, 2, 3 developmental stages

Mycobionta (Fungi)

- Simple structured heterotrophic organisms, lineages derive from basal animal lineages.
- Phylum includes: Chytridiomycota, Zygomycota, Glomeromycota, Ascomycota, Basidiomycota
- Other categories: Deuteromycetes (Fungi imperfecti)
- The Oomycota (water molds) are related to algae within the Heterokontobionta.
- Within the Unikontae, the protozoan-related Acrasiobionta (cellular slime molds) and Myxobionta (slime molds), as well as the Mycobionta (chitin fungi) – related to basic multicellular animals (metazoans) – represent further lineages.
- Independent ectosymbiosis events between various Mycobionta and cyanobacteria or green algae have resulted in the Lichenes (lichens).

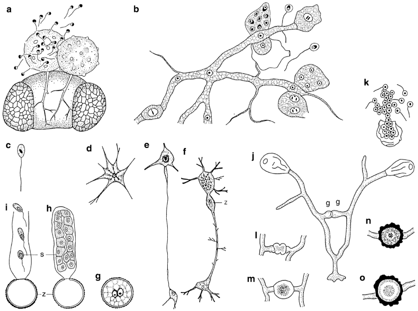


Figure 19: Chytridiomycota, Chytridiomycetes. (a) *Rhizophydium halophilum*, zoosporangia with discharge papillae and with protruding opisthokont zoospores, on a pollen grain of Pinus with haustoria inside (x400). (b) *Polychytrium aggregatum*, small multinuclear tubular mycelium with variously developed sporocysts and two opisthokont zoospores (x400). (c–i) *Polyphagus euglenae* (about x450). (c) Zoospore. (d) Thallus sending out rhizoids. (e) Conjugation between the smaller male and the larger female individual. (f) Male nucleus in the future zygote. (g) Zygote with as yet unjoined male and female nuclei. (h, i) Development and emptying of the zoosporocyst. (j–o) *Zygochytrium aurantiacum* (x350). (j) Hyphae with two final-stage, discharged zoosporangia and two fusing gametangia. (k) Zoosporocyst at discharge. (l–o) Zygote formation between fused gametangia. (o) Mature hypnozygote ('zygospore'). g gametangium, s zoosporocyst, z zygote, zygospore, hypnozygote

Glaucobionta

Divisions/Classes		Chlorophylls *a*	Chlorophylls *b*	Chlorophylls *c*	Phycobilins	Carotenes α	Carotenes β	Diadinoxanthin (C)	Diatoxanthin (C)	Fucoxanthin (D, B, A)	Heteroxanthin (C)	Vaucheriaxanthin (B)	Alloxanthin (C)	Peridinin (D, B)	Lutein	Zeaxanthin	Chrysolaminarin	Starch	Floridean Starch	Paramylon	Plastid Type
Glaucophyta	★	+	–	(·)	+	–	+	–	–	–	–	–	–	–	–	+	–	+	–	–	Cyanelles[a]
Rhodophyta	★	+	–	–	+	(·)	+	–	–	–	–	–	–	–	+	+	–	–	+	–	Rhodoplasts[b]
Cryptophyta	○	+	–	+	+	+	(·)	–	(+)	–	–	–	+	–	–	–	–	+	–	–	
Dinophyta	△(○)	+	–	+	–	–	+	(+)	(+)	(·)	–	–	–	+	–	–	–	+	–	–	
Haptophyta	△	+	–	+	–	–	+	(+)	(+)	+	–	–	–	–	–	–	+	–	–	+	
Heterokontophyta	△	+	–	+	–	–	+	+	(+)	(+)	(+)	(+)	–	–	–	–	+	–	–	–	
Chloromonado-phyceae	△	+	–	+	–	–	+	+	(+)	–	–	–	–	–	–	–	–	–	–	–	
Xanthophyceae	△	+	–	+	–	–	+	+	+	–	+	+	–	–	–	–	+	–	–	–	
Chrysophyceae	△	+	–	+	–	–	+	(+)	(+)	+	–	–	–	–	–	–	+	–	–	–	
Bacillariophyceae	△	+	–	+	–	(·)	+	+	+	+	–	–	–	–	–	–	+	–	–	–	
Phaeophycea	△	+	–	+	–	–	+	(·)	(·)	+	–	–	–	–	–	(+)	+	–	–	–	
Chlorophyta	★	+	+	–	–	(·)	+	–	–	–	–	–	–	–	+	+	–	⊕	–	–	Chloroplasts[c]
Chlorarachniophyta	○	+	+	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	?	
Euglenophyta	△	+	+	–	–	–	+	+	(+)	–	–	–	–	–	–	–	–	–	–	+	
Streptophyta	★	+	+	–	–	–	+	–	–	–	–	–	–	–	–	+	–	⊕	–	–	

After van den Ch. van den Hoeck; summary of the xanthophylls after H. Metzner. 4-Ketocarotene is not included in the table, e.g., echinenone in the Euglenophyta and Chlorophyta as an important pigment or storage polysaccharide and in the Heterokontophyta as a pigment

★ with simple plastids (arose through primary endocytobiosis), ○ with complex plastids and nucleomorph (arose through secondary endocytobiosis), △ with complex plastids without nucleomorph (arose through secondary endocytobiosis), + important pigment or storage polysaccharide, (+) pigment present, (·) pigment rarely present or present only in small quantities, – pigment or storage polysaccharides absent. For starches, + stored outside the chloroplasts, ⊕ stored in the chloroplasts. *A* 8-ketocarotene, e.g., fucoxanthin and siphonoxanthin (latter only in the Prasinophyceae and Chlorophyceae), *B* allene carotenoids, e.g., vaucheriaxanthin and neoxanthin (the latter in the Euglenophyta, Chlorophyta, Eustigmatophyta, Heterokontophyta, and some members of the Rhodophyta), *C* alkyne carotenoids, *D* carotenoid esters, i.e., xanthophylls with a fatty acid on one or both hydroxyl groups

[a]Photosynthetic organelles with peptidoglycan wall

[b]Rhodophyta plastids and their derived photosynthetic organelles

[c]Chlorophyta plastids and their derived photosynthetic organelles

Figure 20: Characteristics of algal classes

Rhodobionta

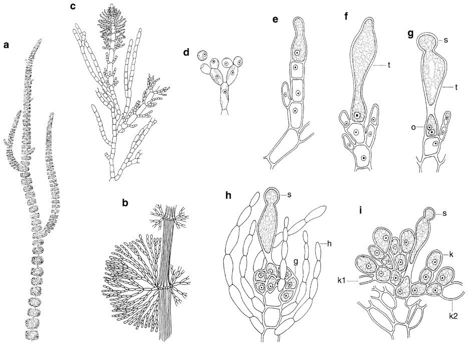


Figure 21: Rhodophyceae, Nemalionales. *Batrachospermum moniliforme*. (a) Habitus (x3). (b) Piece of gametophyte thallus with a whorl of branches (x20). (c) Diploid Chantransia sporophyte with two haploid gametophytes on it (x100). (d) Branch of the gametophyte with four spermatangia, left the emerging spermatium (x540). (e) Carpogonium. (f) Mature carpogonium. (g) Carpogonium after fertilization by spermatium, fusion of the sex nuclei at the base. (h) Diploid carposporophyte with haploid sheath filaments. (i) Mature carposporophyte with carposporocysts. g carposporophyte, h sheath filaments, k1 and k2 emptied carposporocysts, o sex nuclei, s spermatium, t trichogyne

Autotrophic heterokontobionta

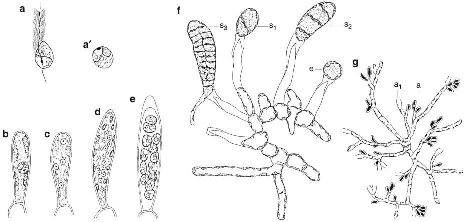


Figure 22: Heterokontophyta, Phaeophyceae, Laminariales. (a–e) Chorda filum. (a) Meiozoospores, (A 0) rounded off for germination (x1,200). (b–e) Development of the unilocular sporocysts (x1,000): (b) uninucleate; (c) tetranucleate; (d) 16-nucleate; (e) with almost complete zoospores. (f, g) Laminaria (x300). (f) Female gametophyte. (g) Male gametophyte. a spermatogonia (a 1 emptied), e egg cell, s 1 –s 3 juvenile sporophytes, still sitting on the emptied oogonium

Chlorobionta ("Viridiplantae")

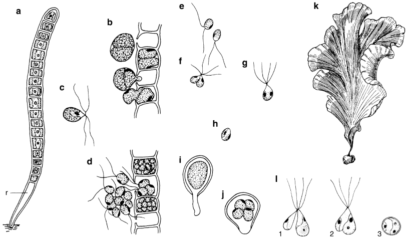


Figure 23: Chlorophyta, Ulvophyceae. (a–j) Ulothrix zonata. (a) Young filament with a rhizoid cell (x300). (b) Piece of filament with emerging zoospores, which arise in pairs in each cell (x480). (c) Quadriflagellate mitozoospore (x480). (d) Formation and emptying of the smaller biflagellate gametes from a filament section (Â480). (e) Gametes (x480). (f) Gamete copulation (x480). (g, h) Zygote (x480). (i) Zygote germinating after the resting phase (x480). (j) Meiozoospore formation in the zygote (x480). (k) Ulva lactuca (sea lettuce) on a rock, marginal cell colorless after zoospore discharge (x0.5). (l) Enteromorpha intestinalis, anisogamete copulation and zygote (x1,800). r rhizoid cell, 1–3 stages up to zygote formation

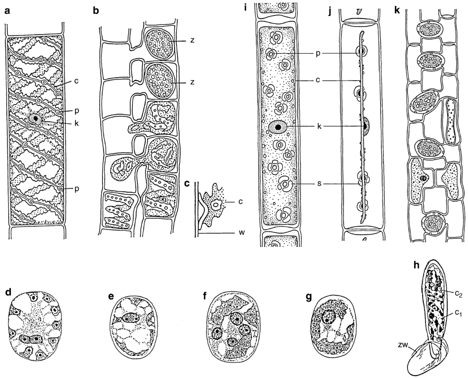


Figure 24: Streptophyta, Zygnematophyceae. (a–h) Spirogyra. (a) S. jugalis – cells (x250). (b) S. quinina – anisogamous copulation (x240). (c–h) S. longata, (c) part of the chloroplast facing the cell wall (x750). (d–h) young and old zygotes, (d) the two sex nuclei before copulation (x250), (e) after fusion (x250), (f) division of the zygote nucleus into four haploid nuclei (x250), (g) the three small nuclei degenerate (x250), (h) uninucleate germ (x180). (i–k) Mougeotia. (i, j M. scalaris – chloroplast (face view and side view, x600). (k) M. calospora – isogamous copulation (x450). c chloroplast(s), k cell nucleus, p pyrenoid, s starch, w cell wall, z zygote, zw zygote wall

Eukarya (alternative classification)

Protists

- Protists exhibit more structural and functional diversity than any other group of eukaryotes; mostly unicellular, but also some colonial and multicellular species.
- Most nutritionally diverse: Photoautotrophs, heterotrophs and mixotrophs.
- Some reproduce exclusively asexually, while other employ sexual process.
- Role of **endosymbiosis**

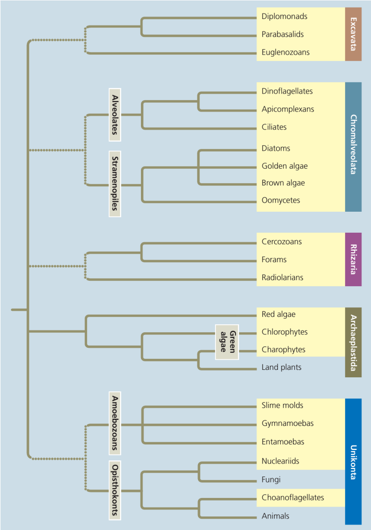
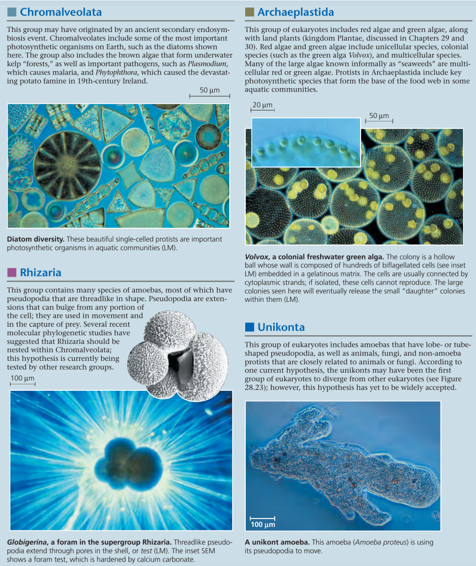


Figure 25: Phylogenetic history of Eukaryota



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 26: Major groups in eukaryota

- **Excavates** include protists with modified mitochondria and protists with unique flagella.
- Includes: Diplomonads (*Giardia* spp), parabasalids (*Trichomonas* spp) and Euglenozoans (*Trypanosoma* spp),
- **Chromalveolata** includes:
    - Alvelolates: Dinoflagellates, Apicomplexans, Cilliates,
    - Stramenopiles: Diatoms, Golden algae, Brown algae, Oomycetes

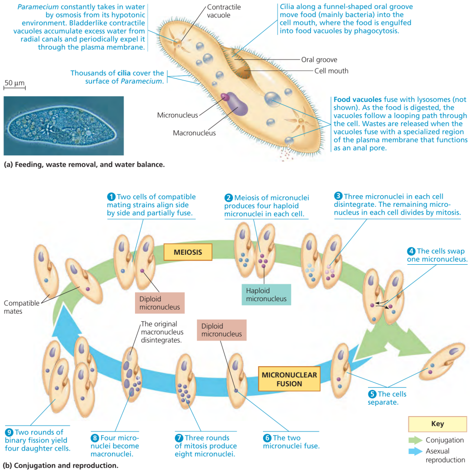


Figure 27: Paramecium function and structure

Stramenopiles

- Photosynthetic organisms (named after *stramen*, straw and *pilos*, hair referring to their characteristic flagellum)
- Important groups:
  - Diatoms: Glass like wall made of hydrated silica. About 100, 000 species. Major component of phytoplankton both in ocean and in lakes.
  - Golden algae: Characteristic color results from their yellow and brown carotenoids. Components of freshwater and marine plankton. Some be mixotrophs. Can survive harsh environments as cysts.
  - Brown algae: Commonly called seaweeds. Most complex multicellular anatomy of all algae. Thallus body may be apparent. e.g. *Laminaria* spp.
  - Oomycetes: Water molds, white rusts and downy mildews. Do not typically photosynthesize. e.g. *Phytophthora* spp.

Figure 28: Diatom

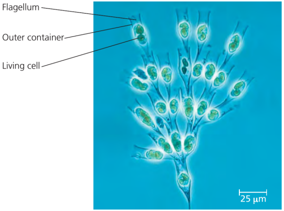


Figure 29: Dinobryon, a colonial golden alga found in fresh water

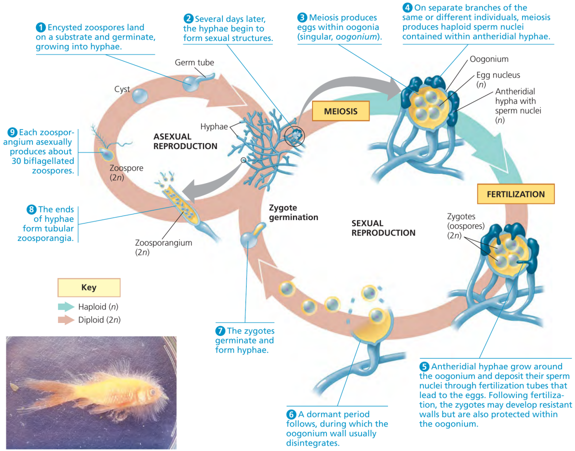


Figure 30: Lifecycle of a water mold

Rhizarians

- Organisms previously referred to as amoebas.
- Move and feed by the means of pseudopodia.
- Includes groups:
  - Radiolarians: Delicate intricately symmetrical internal skeletons made up of silica. The microtubules are covered by a thin layer of cytoplasm, which engulfs smaller microorganisms that become attached to the pseudopodia.
  - Forams: Possess porous shells called tests. Pseudopodia function in swimming, test formation, and feeding. Many forams also derive nourishment from the photosynthesis of symbiotic algae that live within the tests.
  - Cercozoans: Mostly heterotrophs. Bacterial predators but some are rare autotrophs. Amoeboid and flagellated with threadlike pseudopodia.

Archaephlastida

- Red algae
- Green algae:
  - Chlorophytes
  - Charophytes
- Land plants

Photoautotrophs

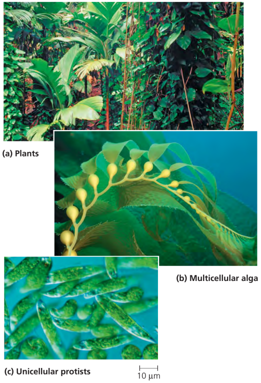


Figure 31: (a) On land, plants are the predominant producers of food. In aquatic environments, photoautotrophs include unicellular and (b) multicellular algae, such as this kelp; (c) some non-algal unicellular protists, such as Euglena;

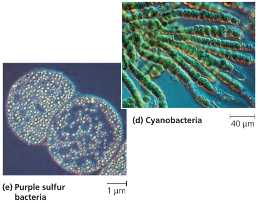


Figure 32: (d) The prokaryotes called cyanobacteria; and (e) other photosynthetic prokaryotes, such as these purple sulfur bacteria, which produce sulfur (the yellow globules within the cells)

Phylogeny of plants and fungi

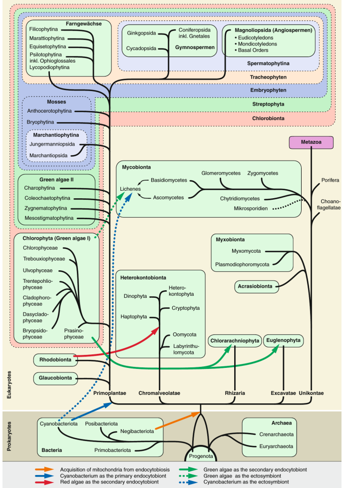


Figure 33: The phylogenetically significant primary and secondary endosymbiotic steps and the resulting acquisition of mitochondria and plastids are marked with arrows. The arrows pointing to the lichens show ectosymbioses with Cyanobacteria and Chlorophyta. Modified from Bresinsky and Kadereit (2006)

Plants (Embryophytoes)

- Arose in Ordovician ($\sim$450 Ma).
- Charophytina (From chlorobionta) and land plants
- The original ancestral land plant lineages are the paraphyletic mosses (Marchantiophytina - liverworts; Bryophytina - foliose mosses; Anthocerophytina - hornworts).
- The paraphyletic pteridophytes (Lycopodiophytina - club mosses, spikemosses, quillworts; Equisetophytina - horsetails; Psilophytina - whisk ferns; Filicophytina - true ferns), together with the monophyletic seed plants (Spermatophytina)

Classification of spermatophytina: Classes

- Cycadopsida
- Ginkgopsida
- Coniferopsida
- Magnoliopsida (Flowering plants):
    - Basal order (Eudicots): Amborellales, Nymphaeales, Austrobaileyales, Ceratophyllales, Chlranthales, Magnoliales, Laurales, Canellales, Piperales
    - Monocotyledons: Acorales, Alismatales, Petrosaviales, Dioscoreales, Pandanales, Liliales, Asparagales
    - Commelinids: Arecales, Poales, Commelinales, Zingiberales
    - Eudicotyledons: Ranunculales, Proteales, Sabiales, Trochodendrales, Buxales, Gunnerales

Classification of spermatophytina: Classes (. . . continued)

- Magnoliopsida (flowering plants):
  - Core eudicots: Berberidopsidales, Dilleniales, Caryophyllales, Santalales, Saxifragales, Vitales
  - Rosids: Crossomatales, Geraniales, Myrtales
  - Fabids: Zygophyllales, Clastrales, Malphighiales, Oxalidales, Fabales, Rosales, Cucurbitales, Fagales
  - Malvids: Huerteales, Brassicales, Malvales, Sapindales
  - Asterids: Cornales, Ericales
  - Lamiids: Garryales, Gentianales, Lamiales, Solanales
  - Campanulids: Aquifoliales, Apiales, Dipsaclales, Asterales.

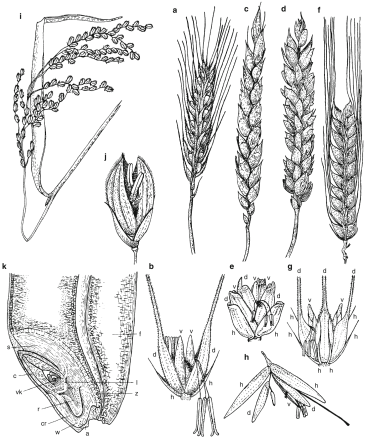


Figure 34: Poales, Poaceae. Grains, spikes, and spikelets. (a, b) Rye, Secale cereale (in b awns only partly shown). (c–e) Wheat, Triticum aestivum with (c) spelt and (d, e) wheat. (f, g) Barley, Hordeum vulgare with (f) two-rowed and (g) six-rowed forms (awns are only partly illustrated). (h) Oats, Avena sativa. (i, j) Rice, Oryza sativa. (k) Wheat grain (caryopsis), median longitudinal section through the lower part, lateral wall of the fruit furrow, below left the embryo with a scutellum, vascular bundle, and cylindrical epithelium, coleoptile, shoot apex, coleorhiza, radicle with root cap, and point of emergence (x14). a point of emergence, c coleoptile, cr coleorhiza, d lemma, f fruit furrow, h glume, l vascular bundle, r radicle, s scutellum, v palea, vk shoot apex, w root cap, z cylindrical epithelium

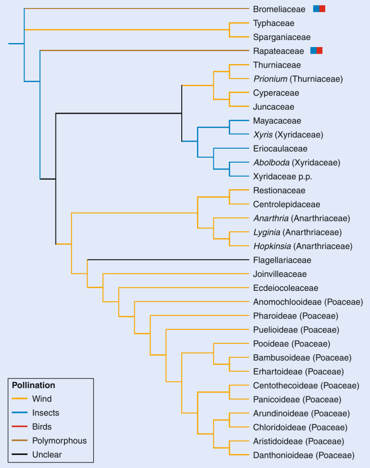


Figure 35: Pollination biology in the poales

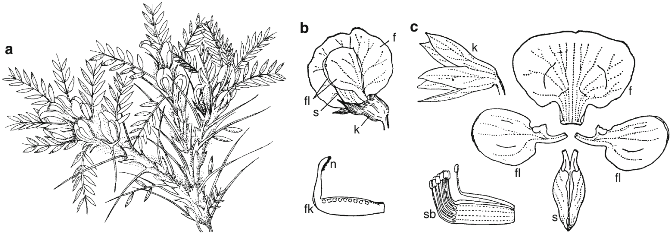


Figure 36: Fabales, Fabaceae, Faboideae. (a) *Astragalus gummifer*, flowering shoot with spines (x0.5). (b, c) *Pisum sativum*. (b) Entire flower (x1) and (c) dissected (x1.2); calyx, corolla made up of flag, wings and keel, stamens (9+1), and monocarpellate ovary with stigma and ovules (dotted). f flag, fk ovary, fl wing, k calyx, n stigma, s keel, sb stamens

Bibliography