

Algae

Algae

- **Phycology** or **algology** is the study of algae.
- The word phycology is derived from the Greek *phykos*, meaning seaweed.
- The algae can be described as eucaryotic organisms that have chlorophyll *a* and carry out oxygen-producing photosynthesis.
- They differ from other photosynthetic eucaryotes in lacking a well-organized vascular conducting system and in having very simple reproductive structures.
- **Distribution:** Algae most commonly occur in water (fresh, marine, or brackish) in which they may be suspended (**planktonic**) or attached and living on the bottom (**benthic**).
- A few algae live at the water-atmosphere interface and are termed **neustonic**.

Classification of Algae

- According to the five-kingdom system of Whittaker, the algae belong to seven divisions distributed between two different kingdoms.
- Based on these properties the algae are arranged by divisions:
- (1) cell wall (if present) chemistry and morphology;
- (2) form in which food or assimilatory products of photosynthesis are stored;
- (3) chlorophyll molecules and accessory pigments that contribute to photosynthesis;
- (4) flagella number and the location of their insertion in motile cells;
- (5) morphology of the cells and/or body (thallus);
- (6) habitat;
- (7) reproductive structures; and
- (8) life history patterns.

Table 26.1 Classical Classification of Algae^a

Division (Common Name)	Kingdom
<i>Chrysophyta</i> (yellow-green and golden-brown algae; diatoms)	<i>Protista</i> (single cell or colonial; eucaryotic)
<i>Euglenophyta</i> (photosynthetic euglenoid flagellates)	<i>Protista</i>
<i>Pyrrophyta</i> (dinoflagellates)	<i>Protista</i>
<i>Charophyta</i> (stoneworts)	<i>Protista</i>
<i>Chlorophyta</i> (green algae)	<i>Protista</i>
<i>Phaeophyta</i> (brown algae)	<i>Plantae</i> (multicellular; eucaryotic)
<i>Rhodophyta</i> (red algae)	<i>Plantae</i>

^aFive-kingdom system.

Molecular Classification

- Molecular systems have placed some of the classical algae:
 - with plants (green algae);
 - some as a separate lineage (red algae);
 - some with the stramenopiles (golden-brown and yellow-green algae, brown algae, and diatoms);
 - some with the alveolates (dinoflagellates); and
 - still others with some protozoa (euglenoids).

Ultrastructure of the Algal Cell

- The eucaryotic algal cell is surrounded by a thin, rigid cell wall.
- Some algae have an outer matrix lying outside the cell wall.
- This usually is flexible and gelatinous, similar to bacterial capsules.
- When present, the flagella are the locomotor organelles.
- The nucleus has a typical nuclear envelope with pores; within the nucleus are a nucleolus, chromatin, and karyolymph.
- The chloroplasts have membrane-bound sacs called thylakoids that carry out the light reactions of photosynthesis.
- These organelles are embedded in the stroma where the dark reactions of carbon dioxide fixation take place.
- A dense proteinaceous area, the **pyrenoid** that is associated with synthesis and storage of starch may be present in the chloroplasts.
- Mitochondrial structure varies greatly in the algae.
- Some algae (euglenoids) have discoid cristae; some, lamellar cristae (green and red algae); and the remaining, (golden-brown and yellow-green, brown, and diatoms) have tubular cristae.

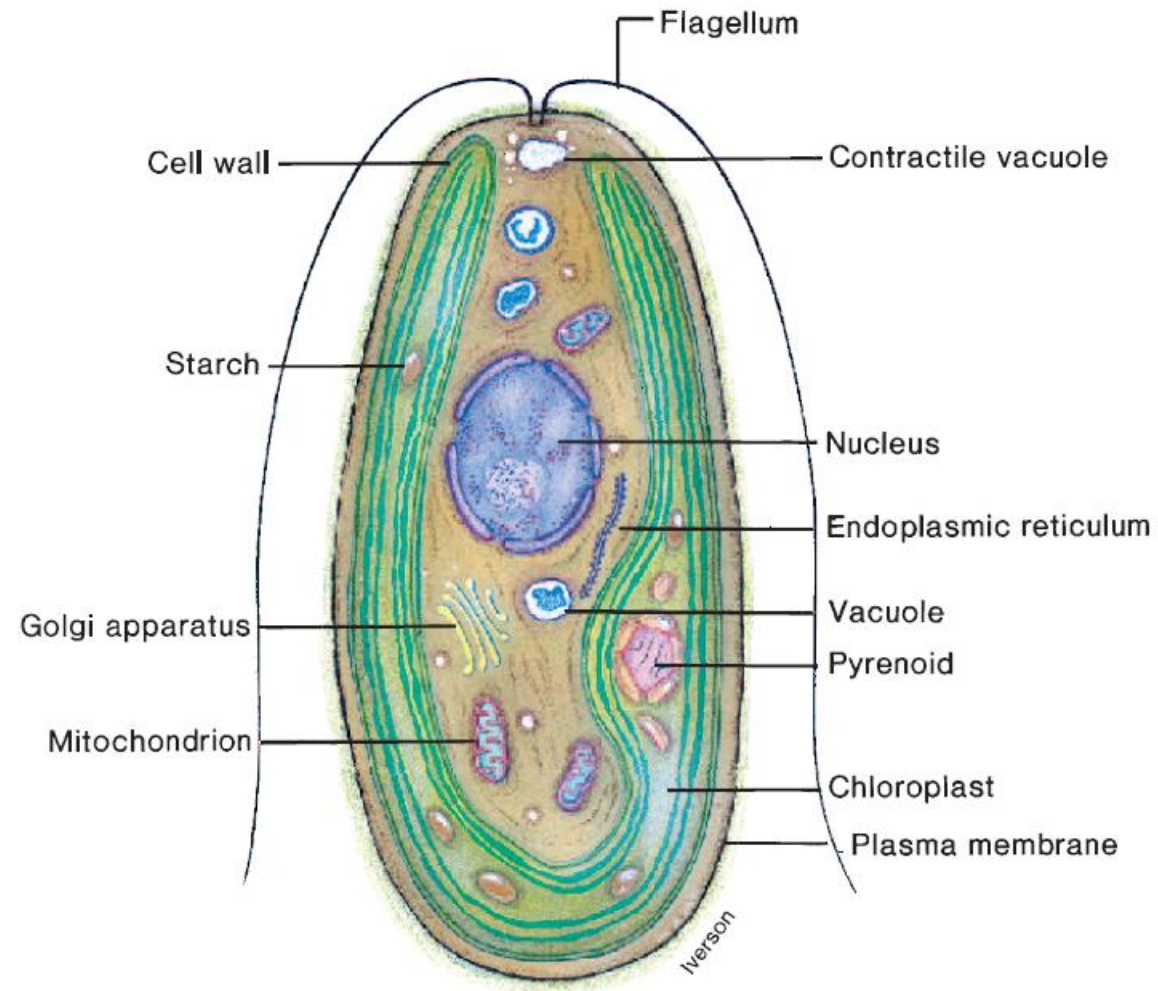


Figure 26.1 Algal Morphology. Schematic drawing of a typical eucaryotic algal cell showing some of its organelles and other structures.

Algal Nutrition

- Algae can be either autotrophic or heterotrophic.
- Most are **photoautotrophic**; they require only light and CO₂ as their principal source of energy and carbon.
- **Chemoheterotrophic** algae are algae that cannot produce sufficient food from sunlight and therefore depend on external organic compounds as both their carbon source and energy source.

Examples

Alga

Euglena gracilis

Chlamydomonas reinhardtii

Chlorella vulgaris

Some dinoflagellates

Organic compounds utilized

Glucose, acetate, ethanol

Acetate

Glucose, acetate

Dissolved organic matter

Structure of the Algal Thallus (Vegetative Form)

- The vegetative body of algae is called the **thallus** [pl., thalli].
- It varies from the relative simplicity of a single cell to the more striking complexity of multicellular forms, such as the giant kelps.
- Single-celled algae may be as small as bacteria, whereas kelp can attain a size over 75 m in length.
- Algae are unicellular (**figure 26.2a,b,g**), colonial (figure 26.2c), filamentous (figure 26.2d), membranous and bladelike (figure 26.2e), or tubular.

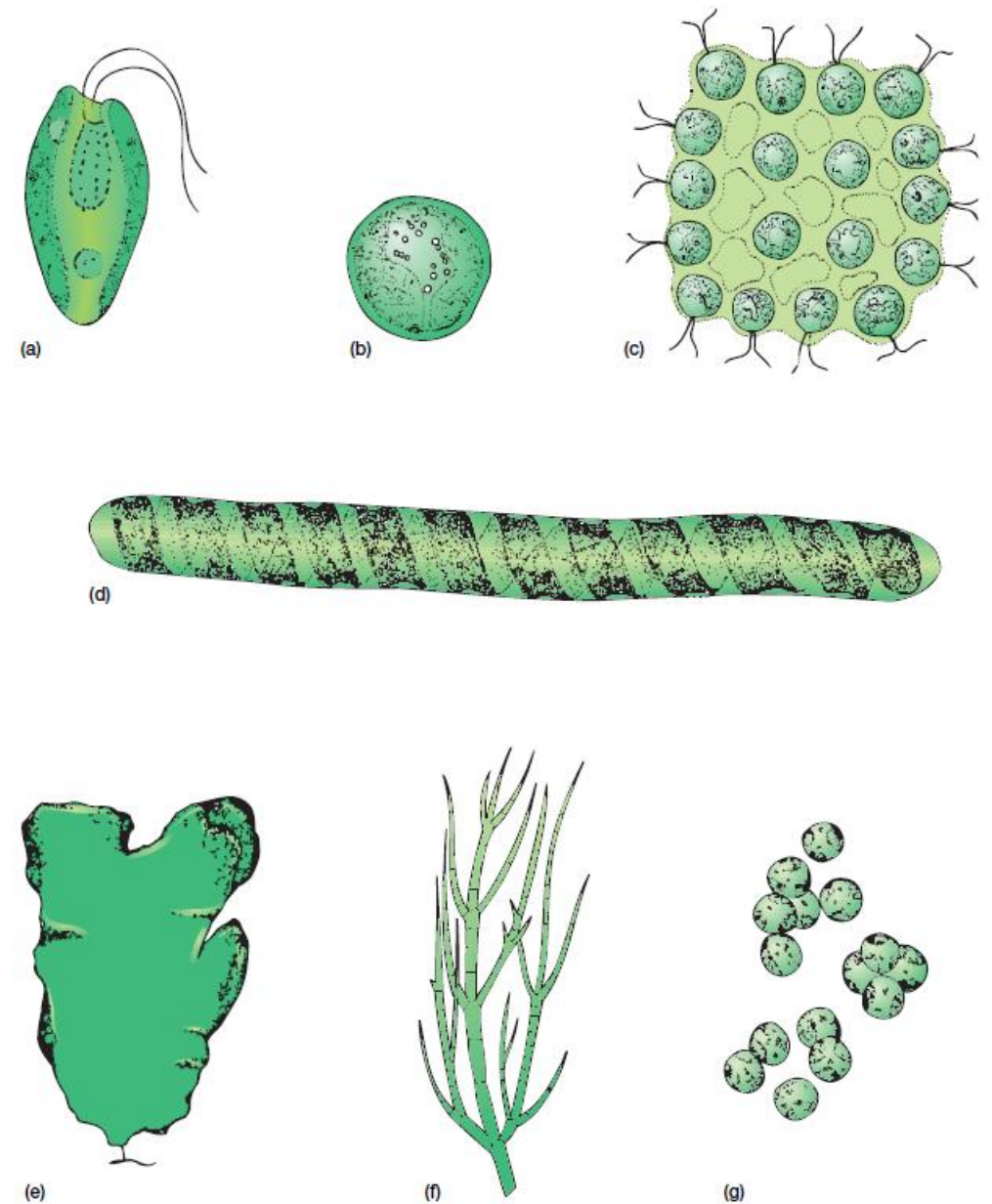


Figure 26.2 Diagrammatic Algal Bodies: (a) unicellular, motile, *Cryptomonas*; (b) unicellular, nonmotile, *Palmellopsis*; (c) colonial, *Gonium*; (d) filamentous, *Spirotaenia*; (e) bladelike kelp, *Monostroma*; (f) leafy tubular axis, branched tufts or plumes, *Stigeoclonium*; (g) unicellular, nonmotile, *Chrysocapsa*.

Algal Reproduction

- Some unicellular algae reproduce asexually. In this kind of reproduction,
- gametes do not fuse to form a zygote.
- There are three basic types of asexual reproduction:
 - fragmentation,
 - spores, and
 - binary fission.
- In **fragmentation** the thallus breaks up and each fragmented part grows to form a new thallus.
- **Spores** can be formed in ordinary vegetative cells or in specialized structures termed sporangia [s., sporangium; Greek *spora*, seed, and *angeion*, vessel].
 - Flagellated motile spores are called **zoospores**.
 - Nonmotile spores produced by sporangia are termed **aplanospores**.
- In some unicellular algae **binary fission** occurs (nuclear division followed by division of the cytoplasm).

Sexual reproduction

- Other algae reproduce sexually.
- Eggs are formed within relatively unmodified vegetative cells called **oogonia** [s., oogonium] that function as female structures.
- Sperm are produced in special male reproductive structures called **antheridia** [s., antheridium].
- In sexual reproduction these gametes fuse to produce a diploid **zygote**.

Comparative Summary of Some Algal Characteristics

Division	Common Name (Representative)	Chlorophylls	Phycobilins	Carotenoids	Storage Products	Flagella	Cell Wall	Habitat	Thylakoids per Stack
Chlorophyta	Green algae (<i>Chlamydomonas</i>)	a, b	–	β-carotene, ± α-carotene, xanthophylls	Sugars, starch, fructosan	1 or 2–8; equal; apical or subapical	Cellulose, mannan, protein, CaCO ₃	fw, bw, sw, t	3–6
Charophyta	Stoneworts/Brittlew orts (<i>Chara</i>)	a, b	–	α-, β-, τ-carotene, xanthophylls	Starch	2; subapical	Cellulose, CaCO ₃	fw, bw	Many
Euglenophyta	Euglenoids (<i>Euglena</i>)	a, b	–	β-carotene, xanthophylls, ± τ-carotene	Paramylon, oils, sugars	1–3; slightly apical	Cell wall absent (protein pellicle present)	fw, bw, sw, t	3
Chrysophyta	Golden-brown, yellow-green algae; diatoms (<i>Cyclotella</i>)	a, c ₁ /c ₂ , rarely d	–	α-, β-, ε-carotene, fucoxanthin, xanthophylls	Chrysolaminarin, oils	1–2; equal or unequal, apical, or absent	Cellulose, silica, CaCO ₃ , chitin, or absent	fw, bw, sw, t	3
Phaeophyta	Brown algae (<i>Sargassum</i>)	a, c	–	β-carotene, fucoxanthin, xanthophylls	Laminarin, mannitol, oils	2; unequal, lateral	Cellulose, alginic acid, fucoidan	bw, sw	3
Rhodophyta	Red algae (<i>Corallina</i>)	a, rarely d	C-phycocyanin, allophycocyanin , phycoerythrin	Xanthophylls (β-carotene, zeaxanthin, ± α-carotene)	Glycogen-like starch (Floridean starch/glycoside)	Absent	Cellulose, xylans, galactans, CaCO ₃	fw, bw, sw	1
Pyrrophyta	Dinoflagellates (<i>Gymnodinium</i>)	a, c ₁ , c ₂	–	β-carotene, fucoxanthin, peridinin, dinoxanthin	Starch, glucan, oils	2; one trailing and one girdling	Cellulose or absent	fw, bw, sw	3

Here is the **merged comparative table** by combining the information from both images. Each row corresponds to the same algal division.

Comparative Summary of Major Algal Divisions

Abbreviations

•**fw** = Fresh water , **bw** = Brackish water, **sw** = Salt water (marine), **t** = Terrestrial

This merged table combines all the major taxonomic, biochemical, structural, and ecological characteristics of the seven principal algal divisions into a single reference table suitable for lecture notes or PowerPoint presentations.

Chlorophyta

- **Morphological characters:**
Green algae exhibit a wide range of thallus organization, including unicellular, colonial, filamentous, sheet-like, siphonaceous (coenocytic), and multicellular forms. The plant body may be microscopic or macroscopic. Many species possess pyrenoids within their chloroplasts for starch synthesis.
- **Pigments:**
The principal pigments are **chlorophyll a and chlorophyll b**, along with β -carotene and xanthophylls, which impart the characteristic green color.
- **Storage products:**
Food is stored mainly as **starch**, along with sugars and fructosan.
- **Flagella:**
Motile cells usually possess **1 to 8 equal, smooth (whiplash) flagella**, which are apical or subapical in position.
- **Cell wall:**
The cell wall is primarily composed of **cellulose**, mannan, and proteins. Some species also contain calcium carbonate (CaCO_3).
- **Habitat:**
Most members are freshwater algae, although marine, brackish-water, and terrestrial species are also common.
- **Representative genera:**
Chlamydomonas, *Volvox*, *Ulothrix*, *Spirogyra*, *Ulva*, and *Chlorella*.
- **Special features:**
 - Largest and most diverse algal division.
 - Chloroplast pigments resemble those of higher plants.
 - Pyrenoids are commonly present.
 - Exhibit all three types of sexual reproduction: isogamy, anisogamy, and oogamy.
 - Considered the evolutionary ancestors of land plants.

Charophyta (Stoneworts)

- **Morphological characters:**
Charophytes are multicellular algae with a highly organized plant body differentiated into nodes, internodes, rhizoids, and whorled branches, closely resembling higher plants.
- **Pigments:**
They contain **chlorophyll a and chlorophyll b**.
- **Storage products:**
Reserve food is stored as **starch**.
- **Flagella:**
Motile reproductive cells possess **two subapical flagella**.
- **Cell wall:**
The cell wall consists of cellulose and is frequently impregnated with **calcium carbonate**, giving the plant a rough texture.
- **Habitat:**
They are almost exclusively freshwater algae.
- **Representative genera:**
Chara and *Nitella*.
- **Special features:**
 - Considered the closest living relatives of terrestrial plants.
 - Possess advanced oogamous reproduction.
 - Often form dense underwater meadows.

Euglenophyta (Euglenoids)

- **Morphological characters:**

Euglenoids are unicellular, spindle-shaped, and highly flexible because they lack a rigid cell wall. Their surface is covered by a proteinaceous pellicle. They possess an eyespot (stigma) and a contractile vacuole.

- **Pigments:**

The photosynthetic species contain **chlorophyll a** and **chlorophyll b**.

- **Storage products:**

Food is stored as **paramylon**, along with oils and sugars.

- **Flagella:**

Usually **one long and one short anterior flagellum** are present.

- **Cell wall:**

A true cell wall is absent; instead, a flexible pellicle surrounds the cell.

- **Habitat:**

Mostly freshwater, although marine and brackish-water species also occur.

- **Representative genera:**

Euglena and *Phacus*.

- **Special features:**

- Can exhibit photoautotrophic, heterotrophic, or mixotrophic nutrition. Many species become **chemoheterotrophic** in darkness.
- Possess positive phototaxis due to the eyespot.
- Commonly used as a model organism in cell biology.

Chrysophyta (Golden-Brown Algae and Diatoms)

- **Morphological characters:**

Most species are unicellular, though some are colonial or filamentous. Diatoms possess a unique siliceous cell wall called a **frustule**, consisting of two overlapping halves.

- **Pigments:**

They contain **chlorophyll a**, **chlorophyll c₁**, **chlorophyll c₂**, and abundant **fucoxanthin**, which gives the golden-brown coloration.

- **Storage products:**

Food is stored as **chrysolaminarin** and oils.

- **Flagella:**

Motile cells possess **one or two unequal flagella**, while many diatoms lack flagella.

- **Cell wall:**

The cell wall may contain **cellulose, silica, chitin, or calcium carbonate** depending on the group.

- **Habitat:**

Widely distributed in freshwater, marine, and brackish-water environments.

- **Representative genera:**

Cyclotella, *Navicula*, and *Pinnularia*.

- **Special features:**

- Diatoms are among the most important primary producers in aquatic ecosystems.
- Their siliceous shells accumulate as **diatomaceous earth**, used in filtration, insulation, abrasives, and polishing materials.
- Fucoxanthin masks the green color of chlorophyll.

Phaeophyta (Brown Algae)

- **Morphological characters:**
Brown algae are almost exclusively multicellular marine seaweeds. The thallus is highly differentiated into a **holdfast**, **stipe**, and **blade**, resembling the roots, stem, and leaves of higher plants.
- **Pigments:**
They contain **chlorophyll a**, **chlorophyll c**, and abundant **fucoxanthin**, which gives the characteristic brown color.
- **Storage products:**
Food is stored as **laminarin**, **mannitol**, and oils.
- **Flagella:**
Motile reproductive cells possess **two unequal lateral flagella**.
- **Cell wall:**
The wall is composed of cellulose embedded in **alginic acid** and **fucoidan**.
- **Habitat:**
Almost entirely marine, particularly in cold and temperate seas.
- **Representative genera:**
Sargassum, *Laminaria*, *Fucus*, and *Macrocystis*.
- **Special features:**
 - Include the largest algae (kelps), which may exceed 60 m in length.
 - Alginic acid is commercially important as a thickener and stabilizer.
 - Form underwater kelp forests that provide habitat for numerous marine organisms.

Rhodophyta (Red Algae)

- **Morphological characters:**
Red algae are mostly multicellular and exhibit filamentous, branched, or fleshy thalli. They lack motile cells throughout their life cycle.
- **Pigments:**
They contain **chlorophyll a**, occasionally chlorophyll d, and phycobilin pigments including **phycoerythrin**, **phycocyanin**, and **allophycocyanin**.
- **Storage products:**
Food is stored as **Floridean starch**.
- **Flagella:**
Flagella are **completely absent** in all stages.
- **Cell wall:**
The cell wall consists of cellulose and galactans. Many species contain **agar** or **carrageenan**, while coralline algae deposit calcium carbonate.
- **Habitat:**
Predominantly marine, especially in deeper waters where blue light penetrates.
- **Representative genera:**
Corallina, *Gelidium*, *Gracilaria*, and *Polysiphonia*.
- **Special features:**
 - The red pigment phycoerythrin enables efficient photosynthesis in deep water.
 - Important commercial source of **agar** and **carrageenan**.
 - Coralline algae contribute to coral reef formation. Absence of flagellated stages is a distinctive feature.

Pyrrhophyta (Dinoflagellates)

- **Morphological characters:**

Dinoflagellates are mostly unicellular planktonic algae. Their cells are often divided into an upper epicone and a lower hypocone by a transverse groove. Many possess cellulose plates forming an armored covering.

- **Pigments:**

They contain **chlorophyll a**, **chlorophyll c₁**, **chlorophyll c₂**, along with **peridinin**, fucoxanthin, and dinoxanthin.

- **Storage products:**

Food is stored as **starch**, glucans, and oils.

- **Flagella:**

They possess **two unequal flagella**—one transverse (girdling) flagellum causing spinning movement and one longitudinal (trailing) flagellum for propulsion.

- **Cell wall:**

The cell wall may contain cellulose plates (theca) or may be absent in naked forms.

- **Habitat:**

Common in marine and freshwater plankton.

- **Representative genera:**

Gymnodinium, *Ceratium*, *Gonyaulax*, and *Noctiluca*.

- **Special features:**

- Responsible for harmful algal blooms or **red tides**.
- Several species produce powerful neurotoxins causing shellfish poisoning.
- Many marine species exhibit **bioluminescence**, producing glowing seawater at night.
- Play an important role in marine planktonic food webs.