Algae

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Algae (/ˈældʒi, ˈælɡi/; singular *alga* /ˈælɡə/) is an informal term for a large, diverse group of photosynthetic organisms which are not necessarily closely related, and is thus polyphyletic. Included organisms range from unicellular genera, such as *Chlorella* and the diatoms, to multicellular forms, such as the giant kelp, a large brown alga which may grow up to 50 m in length. Most are aquatic and autotrophic and lack many of the distinct cell and tissue types, such as stomata, xylem, and phloem, which are found in land plants. The largest and most complex marine algae are called seaweeds, while the most complex freshwater forms are the Charophyta, a division of green algae which includes, for example, *Spirogyra* and the stoneworts.

No definition of algae is generally accepted. One definition is that algae "have chlorophyll as their primary photosynthetic pigment and lack a sterile covering of cells around their reproductive cells".[4] Some authors exclude all prokaryotes[5] thus do not consider cyanobacteria (blue-green algae) as algae.[6]

Algae constitute a polyphyletic group[5] since they do not include a common ancestor, and although their plastids seem to have a single origin, from cyanobacteria,[2] they were acquired in different ways. Green algae are examples of algae that have primary chloroplasts derived from endosymbiotic cyanobacteria. Diatoms and brown algae are examples of algae with secondary chloroplasts derived from an endosymbiotic red alga.[7]

Algae exhibit a wide range of reproductive strategies, from simple asexual cell division to complex forms of sexual reproduction.[8]

Algae lack the various structures that characterize land plants, such as the phyllids (leaf-like structures) of bryophytes, rhizoids in nonvascular plants, and the roots, leaves, and other organs found in tracheophytes (vascular plants). Most are phototrophic, although some are mixotrophic, deriving energy both from photosynthesis and uptake of organic carbon either by osmotrophy,

Algae

Fossil range: Mesoproterozoic–present[1]

Had'n Archean Proterozoic Pha.

A variety of algae growing on the sea bed in shallow waters

Scientific classification

Domain: Eukaryota, Bacteria

Included groups

- Archaeplastida
  - Plantae
    - Chlorophyta (green algae)
    - Charophyta (green algae)
  - Rhodophyta (red algae)
  - Glaucophyta
- Rhizaria, Excavata
  - Chlorarachniophytes
  - Euglenids
- Chromista, Alveolata
  - Heterokonts

myzotrophy, or phagotrophy. Some unicellular species of green algae, many golden algae, euglenids, dinoflagellates, and other algae have become heterotrophs (also called colorless or apochlorotic algae), sometimes parasitic, relying entirely on external energy sources and have limited or no photosynthetic apparatus.[9][10][11] Some other heterotrophic organisms, such as the apicomplexans, are also derived from cells whose ancestors possessed plastids, but are not traditionally considered as algae. Algae have photosynthetic machinery ultimately derived from cyanobacteria that produce oxygen as a by-product of photosynthesis, unlike other photosynthetic bacteria such as purple and green sulfur bacteria. Fossilized filamentous algae from the Vindhya basin have been dated back to 1.6 to 1.7 billion years ago.[12]

Contents

    - Bacillariophyceae (Diatoms)
    - Axodines
    - Bolidomonas
    - Eustigmatophyceae
    - Phaeophyceae (brown algae)
    - Chrysophyceae (golden algae)
    - Raphidophyceae
    - Synurophyceae
    - Xanthophyceae (yellow-green algae)
  - Cryptophyta
  - Dinoflagellata
  - Haptophyta
- Cyanobacteria (blue-green algae)

Excluded groups

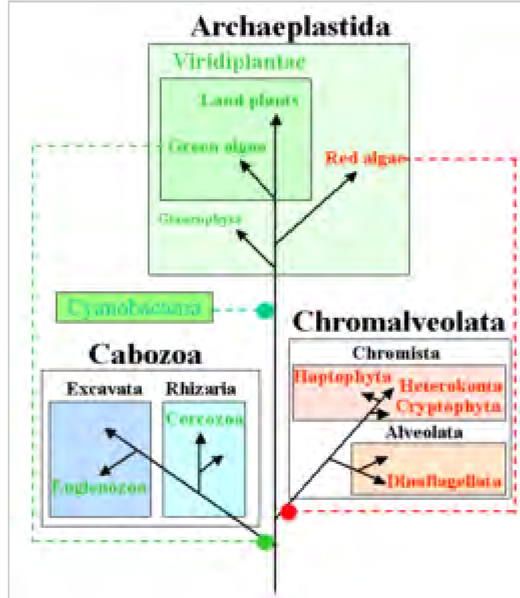
- Bacteria (non-photosynthetic)
- Protista (non-photosynthetic)
- Animalia
- Embryophyta
- Fungi

Etymology and study

The singular *alga* is the Latin word for "seaweed" and retains that meaning in English.[13] The etymology is obscure. Although some speculate that it is related to Latin *algēre*, "be cold",[14] no reason is known to associate seaweed with temperature. A more likely source is *alliga*, "binding, entwining".[15]

The Ancient Greek word for seaweed was φῦκος (*fūkos* or *phykos*), which could mean either the seaweed (probably red algae) or a red dye derived from it. The Latinization, *fūcus*, meant primarily the cosmetic rouge. The etymology is uncertain, but a strong candidate has long been some word related to the Biblical פוך (*pūk*), "paint" (if not that word itself), a cosmetic eye-shadow used by the ancient Egyptians and other inhabitants of the eastern Mediterranean. It could be any color: black, red, green, or blue.[16]

Accordingly, the modern study of marine and freshwater algae is called either phycology or algology, depending on whether the Greek or Latin root is used. The name *Fucus* appears in a number of taxa.

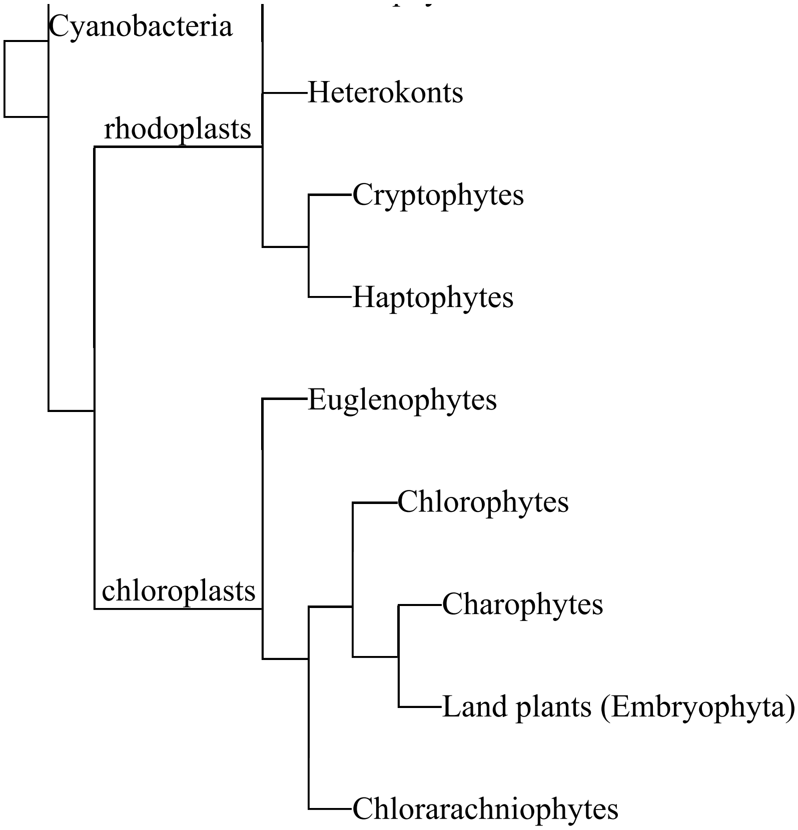


The lineage of algae according to Thomas Cavalier-Smith. The exact number and placement of endosymbiotic events is currently unknown, so this diagram can be taken only as a general guide.[2][3] It represents the most parsimonious way of explaining the three types of endosymbiotic origins of plastids. These types include the endosymbiotic events of cyanobacteria, red algae and green algae, leading to the hypothesis of the supergroups Archaeplastida, Chromalveolata and Cabozoa respectively. Endosymbiotic events are noted with dotted lines.

Classification

Most algae contain chloroplasts that are similar in structure to cyanobacteria. Chloroplasts contain circular DNA like that in cyanobacteria and presumably represent reduced endosymbiotic cyanobacteria. However, the exact origin of the chloroplasts is different among separate lineages of algae, reflecting their acquisition during different endosymbiotic events. The table below describes the composition of the three major groups of algae. Their lineage relationships are shown in the figure in the upper right. Many of these groups contain some members that are no longer photosynthetic. Some retain plastids, but not chloroplasts, while others have lost plastids entirely.

Phylogeny based on plastid[17] not nucleocytoplasmic genealogy:

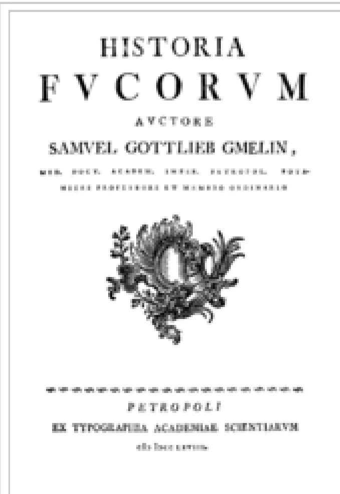


False-color scanning electron micrograph of the unicellular coccolithophore *Gephyrocapsa oceanica*

Supergroup affiliation	Members	Endosymbiont	Summary
Primoplantae/ Archaeplastida	▪ Chlorophyta ▪ Rhodophyta ▪ Glaucophyta	Cyanobacteria	These algae have 'primary' chloroplasts, i.e. the chloroplasts are surrounded by two membranes and probably developed through a single endosymbiotic event. The chloroplasts of red algae have chlorophylls *a* and *c* (often), and phycobilins, while those of green algae have chloroplasts with chlorophyll *a* and *b* without phycobilins. Land plants are pigmented similarly to green algae and probably developed from them, thus the Chlorophyta is a sister taxon to the plants; sometimes the Chlorophyta, the Charophyta, and land plants are grouped together as the Viridiplantae.
Excavata and Rhizaria	▪ Chlorarachniophytes ▪ Euglenids	Green algae	These groups have green chloroplasts containing chlorophylls *a* and *b*.[18] Their chloroplasts are surrounded by four and three membranes, respectively, and were probably retained from ingested green algae. **Chlorarachniophytes**, which belong to the phylum Cercozoa, contain a small nucleomorph, which is a relict of the algae's nucleus. **Euglenids**, which belong to the phylum Euglenozoa, live primarily in fresh water and have chloroplasts with only three membranes. The endosymbiotic green algae may have been acquired through myzocytosis rather than phagocytosis.[19]
Chromista and Alveolata	▪ Heterokonts ▪ Haptophyta ▪ Cryptomonads ▪ Dinoflagellates	Red algae	These groups have chloroplasts containing chlorophylls *a* and *c*, and phycobilins. The shape varies from plant to plant; they may be of discoid, plate-like, reticulate, cup-shaped, spiral, or ribbon shaped. They have one or more pyrenoids to preserve protein and starch. The latter chlorophyll type is not known

			from any prokaryotes or primary chloroplasts, but genetic similarities with red algae suggest a relationship there.[20] In the first three of these groups (Chromista), the chloroplast has four membranes, retaining a nucleomorph in cryptomonads, and they likely share a common pigmented ancestor, although other evidence casts doubt on whether the heterokonts, Haptophyta, and cryptomonads are in fact more closely related to each other than to other groups.[3][21] The typical dinoflagellate chloroplast has three membranes, but considerable diversity exists in chloroplasts within the group, and a number of endosymbiotic events apparently occurred.[2] The Apicomplexa, a group of closely related parasites, also have plastids called apicoplasts, which are not photosynthetic, but appear to have a common origin with dinoflagellate chloroplasts.[2]

Linnaeus, in *Species Plantarum* (1753),[22] the starting point for modern botanical nomenclature, recognized 14 genera of algae, of which only four are currently considered among algae.[23] In *Systema Naturae*, Linnaeus described the genera *Volvox* and *Corallina*, and a species of *Acetabularia* (as *Madrepora*), among the animals.



Title page of Gmelin's *Historia Fucorum*, dated 1768

In 1768, Samuel Gottlieb Gmelin (1744–1774) published the *Historia Fucorum*, the first work dedicated to marine algae and the first book on marine biology to use the then new binomial nomenclature of Linnaeus. It included elaborate illustrations of seaweed and marine algae on folded leaves.[24][25]

W.H.Harvey (1811—1866) and Lamouroux (1813)[26] were the first to divide macroscopic algae into four divisions based on their pigmentation. This is the first use of a biochemical criterion in plant systematics. Harvey's four divisions are: red algae (Rhodospermae), brown algae (Melanospermae), green algae (Chlorospermae), and Diatomaceae.[27][28]

At this time, microscopic algae were discovered and reported by a different group of workers (e.g., O. F. Müller and Ehrenberg) studying the Infusoria (microscopic organisms). Unlike macroalgae, which were clearly viewed as plants, microalgae were frequently considered animals because they are often motile.[29] Even the nonmotile (coccoid) microalgae were sometimes merely seen as stages of the lifecycle of plants, macroalgae, or animals.[30][31]

Although used as a taxonomic category in some pre-Darwinian classifications, e.g., Linnaeus (1753), de Jussieu (1789), Horaninow (1843), Agassiz (1859), Wilson & Cassin (1864), in further classifications, the "algae" are seen as an artificial, polyphyletic group.

Throughout the 20th century, most classifications treated the following groups as divisions or classes of algae: cyanophytes, rhodophytes, chrysophytes, xanthophytes, bacillariophytes, phaeophytes, pyrrhophytes (cryptophytes and dinophytes), euglenophytes, and chlorophytes. Later, many new groups were discovered (e.g., Bolidophyceae), and others were splintered from older groups: charophytes and glaucophytes (from chlorophytes), many heterokontophytes (e.g., synurophytes from chrysophytes, or eustigmatophytes from xanthophytes), haptophytes (from chrysophytes), and chlorarachniophytes (from xanthophytes).

With the abandonment of plant-animal dichotomous classification, most groups of algae (sometimes all) were included in Protista, later also abandoned in favour of Eukaryota. However, as a legacy of the older plant life scheme, some groups that were also treated as protozoans in the past still have duplicated classifications (see ambiregnal protists).

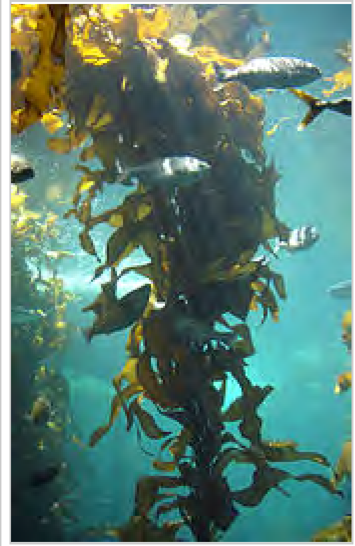
Some parasitic algae (e.g., the green algae *Prototheca* and *Helicosporidium*, parasites of metazoans, or *Cephaleuros*, parasites of plants) were originally classified as fungi, sporozoans, or protistans of *incertae sedis*,[32] while others (e.g., the green algae *Phyllosiphon* and *Rhodochytrium*, parasites of plants, or the red algae *Pterocladiophila* and *Gelidiocolax mammillatus*, parasites of other red algae, or the dinoflagellates *Oodinium*, parasites of fish) had their relationship with algae conjectured early. In other cases, some groups were originally characterized as parasitic algae (e.g., *Chlorochytrium*), but later were seen as endophytic algae.[33] Some filamentous bacteria (e.g., *Beggiatoa*) were originally seen as algae. Furthermore, groups like the apicomplexans are also parasites derived from ancestors that possessed plastids, but are not included in any group traditionally seen as algae.

Relationship to land plants

The first land plants probably evolved from shallow freshwater charophyte algae much like *Chara* almost 500 million years ago. These probably had an isomorphic alternation of generations and were probably filamentous. Fossils of isolated land plant spores suggest land plants may have been around as long as 475 million years ago.[34][35]

Morphology

A range of algal morphologies is exhibited, and convergence of features in unrelated groups is common. The only groups to exhibit three-dimensional multicellular thalli are the reds and browns, and some chlorophytes.[36] Apical growth is constrained to subsets of these groups: the florideophyte reds, various browns, and the charophytes.[36] The form of charophytes is quite different from those of reds and browns, because they have distinct nodes, separated by internode 'stems'; whorls of branches reminiscent of the horsetails occur at the nodes.[36] Conceptacles are another polyphyletic trait; they appear in the coralline algae and the Hildenbrandiales, as well as the browns.[36]



The kelp forest exhibit at the Monterey Bay Aquarium: A three-dimensional, multicellular thallus

Most of the simpler algae are unicellular flagellates or amoeboids, but colonial and nonmotile forms have developed independently among several of the groups. Some of the more common organizational levels, more than one of which may occur in the lifecycle of a species, are

- Colonial: small, regular groups of motile cells
- Capsoid: individual non-motile cells embedded in mucilage
- Coccoid: individual non-motile cells with cell walls
- Palmelloid: nonmotile cells embedded in mucilage
- Filamentous: a string of nonmotile cells connected together, sometimes branching
- Parenchymatous: cells forming a thallus with partial differentiation of tissues

In three lines, even higher levels of organization have been reached, with full tissue differentiation. These are the brown algae,[37]—some of which may reach 50 m in length (kelps)[38]—the red algae,[39] and the green algae.[40] The most complex forms are found among the green algae (see Charales and Charophyta), in a lineage that eventually led to the higher land plants. The point where these nonalgal plants begin and algae stop is usually taken to be the presence of reproductive organs with protective cell layers, a characteristic not found in the other algal groups.

Physiology

Many algae, particularly members of the Characeae,[41] have served as model experimental organisms to understand the mechanisms of the water permeability of membranes, osmoregulation, turgor regulation, salt tolerance, cytoplasmic streaming, and the generation of action potentials.

Phytohormones are found not only in higher plants, but in algae, too.[42]

Symbiotic algae

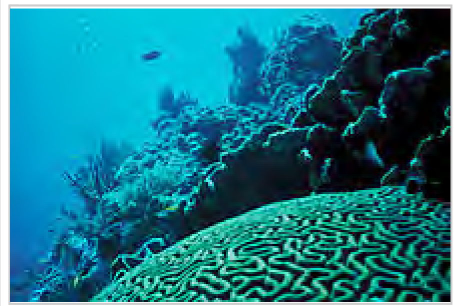
Some species of algae form symbiotic relationships with other organisms. In these symbioses, the algae supply photosynthates (organic substances) to the host organism providing protection to the algal cells. The host organism derives some or all of its energy requirements from the algae. Examples are:

Lichens


Rock lichens in Ireland

Lichens are defined by the International Association for Lichenology to be "an association of a fungus and a photosynthetic symbiont resulting in a stable vegetative body having a specific structure."[43] The fungi, or mycobionts, are mainly from the Ascomycota with a few from the Basidiomycota. They are not found alone in nature; but when they began to associate is not known.[44] One mycobiont associates with the same phycobiont species, rarely two, from the green algae, except that alternatively, the mycobiont may associate with a species of cyanobacteria (hence "photobiont" is the more accurate term). A photobiont may be associated with many different mycobionts or may live independently; accordingly, lichens are named and classified as fungal species.[45] The association is termed a morphogenesis because the lichen has a form and capabilities not possessed by the symbiont species alone (they can be experimentally isolated). The photobiont possibly triggers otherwise latent genes in the mycobiont.[46]

Coral reefs


Floridian coral reef

Coral reefs are accumulated from the calcareous exoskeletons of marine invertebrates of the order Scleractinia (stony corals). These animals metabolize sugar and oxygen to obtain energy for their cell-building processes, including secretion of the exoskeleton, with water and carbon dioxide as byproducts. Dinoflagellates (algal protists) are often endosymbionts in the cells of the coral-forming marine invertebrates, where they accelerate host-cell metabolism by generating immediately available sugar and oxygen through photosynthesis using incident light and the carbon dioxide produced by the host. Reef-building stony corals (hermatypic corals) require endosymbiotic algae from the genus *Symbiodinium* to be in a healthy condition.[47] The loss of *Symbiodinium* from the host is known as coral bleaching, a condition which leads to the deterioration of a reef.

Sea sponges

Green algae live close to the surface of some sponges, for example, breadcrumb sponge (*Halichondria panicea*). The alga is thus protected from predators; the sponge is provided with oxygen and sugars which can account for 50 to 80% of sponge growth in some species.[48]

Lifecycle

Rhodophyta, Chlorophyta, and Heterokontophyta, the three main algal divisions, have lifecycles which show considerable variation and complexity. In general, an asexual phase exists where the seaweed's cells are diploid, a sexual phase where the cells are haploid, followed by fusion of the male and female gametes. Asexual reproduction permits efficient population increases, but less variation is possible.

Commonly, in sexual reproduction of unicellular and colonial algae, two specialized, sexually compatible, haploid gametes make physical contact and fuse to form a zygote. To ensure a successful mating, the development and release of gametes is highly synchronized and regulated; pheromones may play a key role in these processes.[49] Sexual reproduction allows for more variation and provides the benefit of efficient recombinational repair of DNA damages during meiosis, a key stage of the sexual cycle.[50] However, sexual reproduction is more costly than asexual reproduction.[51] Meiosis has been shown to occur in many different species of algae.[52]

Numbers

Algae on coastal rocks at Shihtiping in Taiwan

The *Algal Collection of the US National Herbarium* (located in the National Museum of Natural History) consists of approximately 320,500 dried specimens, which, although not exhaustive (no exhaustive collection exists), gives an idea of the order of magnitude of the number of algal species (that number remains unknown).[53] Estimates vary widely. For example, according to one standard textbook,[54] in the British Isles the *UK Biodiversity Steering Group Report* estimated there to be 20,000 algal species in the UK. Another checklist reports only about 5,000 species. Regarding the difference of about 15,000 species, the text concludes: "It will require many detailed field surveys before it is possible to provide a reliable estimate of the total number of species ..."

Regional and group estimates have been made, as well:

- 5,000–5,500 species of red algae worldwide
- "some 1,300 in Australian Seas"[55]
- 400 seaweed species for the western coastline of South Africa,[56] and 212 species from the coast of KwaZulu-Natal.[57] Some of these are duplicates, as the range extends across both coasts, and the total recorded is probably about 500 species. Most of these are listed in List of seaweeds of South Africa. These exclude phytoplankton and crustose corallines.
- 669 marine species from California (US)[58]
- 642 in the check-list of Britain and Ireland[59]

and so on, but lacking any scientific basis or reliable sources, these numbers have no more credibility than the British ones mentioned above. Most estimates also omit microscopic algae, such as phytoplankton.

The most recent estimate suggests 72,500 algal species worldwide.[60]

Distribution

The distribution of algal species has been fairly well studied since the founding of phytogeography in the mid-19th century.[61] Algae spread mainly by the dispersal of spores analogously to the dispersal of Plantae by seeds and spores. This dispersal can be accomplished by air, water, or other organisms. Due to this, spores can be found in a variety of environments: fresh and marine waters, air, soil, and in or on other organisms.[61] Whether a spore is to grow into an organism depends on the combination of the species and the environmental conditions where the spore lands.

The spores of freshwater algae are dispersed mainly by running water and wind, as well as by living carriers.[61] However, not all bodies of water can carry all species of algae, as the chemical composition of certain water bodies limits the algae that can survive within them.[61] Marine spores are often spread by ocean currents. Ocean water presents many vastly different habitats based on temperature and nutrient availability, resulting in phytogeographic zones, regions, and provinces.[62]

To some degree, the distribution of algae is subject to floristic discontinuities caused by geographical features, such as Antarctica, long distances of ocean or general land masses. It is, therefore, possible to identify species occurring by locality, such as "Pacific algae" or "North Sea algae". When they occur out of their localities, hypothesizing a transport mechanism is usually possible, such as the hulls of ships. For example, *Ulva reticulata* and *U. fasciata* travelled from the mainland to Hawaii in this manner.

Mapping is possible for select species only: "there are many valid examples of confined distribution patterns."[63] For example, *Clathromorphum* is an arctic genus and is not mapped far south of there.[64] However, scientists regard the overall data as insufficient due to the "difficulties of undertaking such studies."[65]

Ecology

Phytoplankton, Lake Chuzenji

Algae are prominent in bodies of water, common in terrestrial environments, and are found in unusual environments, such as on snow and ice. Seaweeds grow mostly in shallow marine waters, under 100 m (330 ft) deep; however, some have been recorded to a depth of 360 m (1,180 ft).[66]

The various sorts of algae play significant roles in aquatic ecology. Microscopic forms that live suspended in the water column (phytoplankton) provide the food base for most marine food chains. In very high densities (algal blooms), these algae may discolor the water and outcompete, poison, or asphyxiate other life forms.

Algae can be used as indicator organisms to monitor pollution in various aquatic systems.[67] In many cases, algal metabolism is sensitive to various pollutants. Due to this, the species composition of algal populations may shift in the presence of chemical pollutants.[67] To detect these changes, algae can be sampled from the environment and maintained in laboratories with relative ease.[67]

On the basis of their habitat, algae can be categorized as: aquatic (planktonic, benthic, marine, freshwater, lentic, lotic),[68] terrestrial, aerial (subareial),[69] lithophytic, halophytic (or euryhaline), psammon, thermophilic, cryophilic, epibiont (epiphytic, epizoic), endosymbiont (endophytic, endozoic), parasitic, calcifilic or lichenic (phycobiont).[70]

Cultural associations

In classical Chinese, the word 藻 is used both for "algae" and (in the modest tradition of the imperial scholars) for "literary talent". The third island in Kunming Lake beside the Summer Palace in Beijing is known as the Zaojian Tang Dao, which thus simultaneously means "Island of the Algae-Viewing Hall" and "Island of the Hall for Reflecting on Literary Talent".

Uses

Agar


Harvesting algae

Agar, a gelatinous substance derived from red algae, has a number of commercial uses.[71] It is a good medium on which to grow bacteria and fungi, as most microorganisms cannot digest agar.

Alginates

Alginic acid, or alginate, is extracted from brown algae. Its uses range from gelling agents in food, to medical dressings. Alginic acid also has been used in the field of biotechnology as a biocompatible medium for cell encapsulation and cell immobilization. Molecular cuisine is also a user of the substance for its gelling properties, by which it becomes a delivery vehicle for flavours.

Between 100,000 and 170,000 wet tons of *Macrocystis* are harvested annually in New Mexico for alginate extraction and abalone feed.[72][73]

Energy source

To be competitive and independent from fluctuating support from (local) policy on the long run, biofuels should equal or beat the cost level of fossil fuels. Here, algae-based fuels hold great promise,[74][75] directly related to the potential to produce more biomass per unit area in a year than any other form of biomass. The break-even point for algae-based biofuels is estimated to occur by 2025.[76]

Fertilizer

For centuries, seaweed has been used as a fertilizer; George Owen of Henllys writing in the 16th century referring to drift weed in South Wales:[77]

> This kind of ore they often gather and lay on great heapes, where it heteth and rotteth, and will have a strong and loathsome smell; when being so rotten they cast on the land, as they do their muck, and thereof springeth good corn, especially barley ... After spring-tydes or great rigs of the sea, they fetch it in sacks on horse backes, and carie the same three, four, or five miles, and cast it on the lande, which doth very much better the ground for corn and grass.


Seaweed-fertilized gardens on Inisheer

Today, algae are used by humans in many ways; for example, as fertilizers, soil conditioners, and livestock feed.[78] Aquatic and microscopic species are cultured in clear tanks or ponds and are either harvested or used to treat effluents pumped through the ponds. Algaculture on a large scale is an important type of aquaculture in some places. Maerl is commonly used as a soil conditioner.

Nutrition


Dulse, a type of food

Naturally growing seaweeds are an important source of food, especially in Asia. They provide many vitamins including: A, B_1, B_2, B_6, niacin, and C, and are rich in iodine, potassium, iron, magnesium, and calcium.[79] In addition, commercially cultivated microalgae, including both algae and cyanobacteria, are marketed as nutritional supplements, such as spirulina,[80] *Chlorella* and the vitamin-C supplement from *Dunaliella*, high in beta-carotene.

Algae are national foods of many nations: China consumes more than 70 species, including *fat choy*, a cyanobacterium considered a vegetable; Japan, over 20 species;[81] Ireland, dulse; Chile, cochayuyo.[82] Laver is used to make "laver bread" in Wales, where it is known as *bara lawr*; in Korea, *gim*; in Japan, *nori* and *aonori*. It is also used along the west coast of North America from California to British Columbia, in Hawaii and by the Māori of New Zealand. Sea lettuce and badderlocks are salad ingredients in Scotland, Ireland, Greenland, and Iceland.

The oils from some algae have high levels of unsaturated fatty acids. For example, *Parietochloris incisa* is very high in arachidonic acid, where it reaches up to 47% of the triglyceride pool.[83] Some varieties of algae favored by vegetarianism and veganism contain the long-chain, essential omega-3 fatty acids, docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). Fish oil contains the omega-3 fatty acids, but the original source is algae (microalgae in particular), which are eaten by marine life such as copepods and are passed up the food chain.[84] Algae have emerged in recent years as a popular source of omega-3 fatty acids for vegetarians who cannot get long-chain EPA and DHA from other vegetarian sources such as flaxseed oil, which only contains the short-chain alpha-linolenic acid (ALA).

Pollution control

- Sewage can be treated with algae, reducing the use of large amounts of toxic chemicals that would otherwise be needed.
- Algae can be used to capture fertilizers in runoff from farms. When subsequently harvested, the enriched algae can be used as fertilizer.
- Aquaria and ponds can be filtered using algae, which absorb nutrients from the water in a device called an algae scrubber, also known as an algae turf scrubber.[85][86][87][88]

Agricultural Research Service scientists found that 60–90% of nitrogen runoff and 70–100% of phosphorus runoff can be captured from manure effluents using a horizontal algae scrubber, also called an algal turf scrubber (ATS). Scientists developed the ATS, which consists of shallow, 100-foot raceways of nylon netting where algae colonies can form, and studied its efficacy for three years. They found that algae can readily be used to reduce the nutrient runoff from agricultural fields and increase the quality of water flowing into rivers, streams, and oceans. Researchers collected and dried the nutrient-rich algae from the ATS and studied its potential as an organic fertilizer. They found that cucumber and corn seedlings grew just as well using ATS organic fertilizer as they did with commercial fertilizers.[89] Algae scrubbers, using bubbling upflow or vertical waterfall versions, are now also being used to filter aquaria and ponds.

Bioremediation

The alga *Stichococcus bacillaris* has been seen to colonize silicone resins used at archaeological sites; biodegrading the synthetic substance.[90]

Pigments

The natural pigments (carotenoids and chlorophylls) produced by algae can be used as alternatives to chemical dyes and coloring agents.[91] The presence of some individual algal pigments, together with specific pigment concentration ratios, are taxon-specific: analysis of their concentrations with various analytical methods, particularly high-performance liquid chromatography, can therefore offer deep insight into the taxonomic composition and relative abundance of natural alga populations in sea water samples.[92][93]

Stabilizing substances

Carrageenan, from the red alga *Chondrus crispus*, is used as a stabilizer in milk products.

See also

- AlgaeBase
- AlgaePARC
- Toxoid - anatoxin
- Eutrophication
- *Marimo* algae
- Iron fertilization
- Microbiofuels

- Microphyte
- Photobioreactor
- Plant

References

1. N. J. Butterfield (2000). "*Bangiomorpha pubescens* n. gen., n. sp.: implications for the evolution of sex, multicellularity, and the Mesoproterozoic/Neoproterozoic radiation of eukaryotes". *Paleobiology*. **26** (3): 386–404. doi:10.1666/0094-8373(2000)026<0386:BPNGNS>2.0.CO;2. ISSN 0094-8373.
2. Patrick J. Keeling (2004). "Diversity and evolutionary history of plastids and their hosts". *American Journal of Botany*. **91** (10): 1481–1493. doi:10.3732/ajb.91.10.1481. PMID 21652304.
3. Laura Wegener Parfrey, Erika Barbero, Elyse Lasser, Micah Dunthorn, Debashish Bhattacharya, David J Patterson, and Laura A Katz (December 2006). "Evaluating Support for the Current Classification of Eukaryotic Diversity". *PLoS Genet*. **2** (12): e220. doi:10.1371/journal.pgen.0020220. PMC 1713255. PMID 17194223.
4. Lee, R. E. (2008). *Phycology*. Cambridge University Press.
5. Nabors, Murray W. (2004). *Introduction to Botany*. San Francisco, CA: Pearson Education, Inc. ISBN 978-0-8053-4416-5.
6. Allaby, M., ed. (1992). "Algae". *The Concise Dictionary of Botany*. Oxford: Oxford University Press.
7. J.D. Palmer, D.E. Soltis, M.W. Chase (2004). "The plant tree of life: an overview and some points of view". *Am. J. Bot*. **91** (10): 1437–1445. doi:10.3732/ajb.91.10.1437. PMID 21652302.
8. Smithsonian National Museum of Natural History; Department of Botany. http://botany.si.edu/projects/algae/introduction.htm
9. Pringsheim, E.G. 1963. *Farblose Algen. Ein beitrag zur Evolutionsforschung*. Gustav Fischer Verlag, Stuttgart. 471 pp., species:Algae#Pringsheim .281963.29.
10. Tartar, A., Boucias, D. G., Becnel, J. J., and Adams, B. J. (2003). "Comparison of plastid 16S rRNA (rrn 16) genes from Helicosporidium spp.: evidence supporting the reclassification of Helicosporidia as green algae (Chlorophyta)". *International Journal of Systematic and Evolutionary Microbiology*. **53** (Pt 6): 1719–1723. doi:10.1099/ijs.0.02559-0. PMID 14657099.
11. Figueroa-Martinez, F.; Nedelcu, A. M.; Smith, D. R.; Reyes-Prieto, A. (2015). "When the lights go out: the evolutionary fate of free-living colorless green algae". *New Phytologist*. **206** (3): 972–982. doi:10.1111/nph.13279.
12. Bengtson, S; Belivanova, V; Rasmussen, B; Whitehouse, M (2009). "The controversial "Cambrian" fossils of the Vindhyan are real but more than a billion years older". *Proceedings of the National Academy of Sciences of the United States of America*. **106** (19): 7729–34. Bibcode:2009PNAS..106.7729B. doi:10.1073/pnas.0812460106. PMC 2683128. PMID 19416859.
13. "alga, algae". *Webster's Third New International Dictionary of the English Language Unabridged with Seven Language Dictionary*. **1**. Encyclopædia Britannica, Inc. 1986.
14. Partridge, Eric (1983). "algae". *Origins*.
15. Lewis, Charlton T.; Charles Short (1879). *alga*. Oxford: Clarendon Press. ISBN 978-0-19-864201-5.
16. Thomas Kelly Cheyne; John Sutherland Black (1902). *Encyclopædia biblica: a critical dictionary of the literary, political and religious history, the archæology, geography, and natural history of the Bible*. Macmillan Company. p. 3525.
17. Bhattacharya, D.; Medlin, L. (1998). "Algal Phylogeny and the Origin of Land Plants" (PDF). *Plant Physiology*. **116** (1): 9–15. doi:10.1104/pp.116.1.9.
18. Losos, Jonathan B.; Mason, Kenneth A.; Singer, Susan R. (2007). *Biology* (8 ed.). McGraw-Hill. ISBN 978-0-07-304110-0.
19. Archibald JM; Keeling PJ (November 2002). "Recycled plastids: a 'green movement' in eukaryotic evolution". *Trends in Genetics*. **18** (11): 577–584. doi:10.1016/S0168-9525(02)02777-4. PMID 12414188.
20. Janson, Sven; Graneli, Edna (September 2003). "Genetic analysis of the psbA gene from single cells indicates a cryptomonad origin of the plastid in Dinophysis (Dinophyceae)". *Phycologia*. Allen Press Publishing Services. **42** (5): 473–477. doi:10.2216/i0031-8884-42-5-473.1. ISSN 0031-8884.

21. Burki F, Shalchian-Tabrizi K, Minge M, Skjæveland Å, Nikolaev SI et al. (2007). Butler, Geraldine, ed. "Phylogenomics Reshuffles the Eukaryotic Supergroups". *PLOS ONE*. **2** (8): e790. Bibcode:2007PLoSO...2..790B. doi:10.1371/journal.pone.0000790. PMC 1949142. PMID 17726520.
22. Linnæus, C. (1753). *Species Plantarum*, vol. 2, p. 1131, [1] (http://www.biodiversitylibrary.org/item/13830#page/573/mode/1up).
23. Sharma, O. P. (1986). Textbook of Algae. McGraw Hill. p. 22, [2] (https://books.google.com/books?id=hOa74Hm4zDIC&lpg=PP1&hl=en&pg=PA22).
24. Gmelin S G (1768) *Historia Fucorum* (https://books.google.co.nz/books?id=YUAAAAAAQAAJ&printsec=frontcover&dq=%22Historia+Fucorum%22&hl=en) Ex typographia Academiae scientiarum, St. Petersburg.
25. Silva PC, Basson PW and Moe RL (1996) *Catalogue of the Benthic Marine Algae of the Indian Ocean* (https://books.google.co.nz/books?id=vuWEemVY8WEC&pg=PA2&lpg=PA2&dq=%22Historia+Fucorum%22+binomial+nomenclature&source=bl&hl=en) page 2, University of California Press. ISBN 978-0-520-91581-7.
26. Medlin, L. K., W. H. C. F. Kooistra, D. Potter, G. W. Saunders, and R. A. Anderson (1997). Phylogenetic relationships of the "golden algae" (haptophytes, heterokont chromophytes) and their plastids. (http://epic.awi.de/2100/1/Med1997c.pdf) *Plant Systematics and Evolution*, p. 188.
27. Dixon, P S (1973). *Biology of the Rhodophyta*. Edinburgh: Oliver & Boyd. p. 232. ISBN 978-0-05-002485-0.
28. Harvey, D. (1836). *Flora hibernica (http://images.algaebase.org/pdf/562E38EB0a0fc2A17Eukv24B7E9F/18893.pdf)*.
29. Medlin et al. (1997), p. 188.
30. Braun, A. *Algarum unicellularium genera nova et minus cognita, praemissis observationibus de algis unicellularibus in genere (New and less known genera of unicellular algae, preceded by observations respecting unicellular algae in general) (http://www.biodiversitylibrary.org/bibliography/2057#/summary).* Lipsiae, Apud W. Engelmann, 1855. Translation at: Lankester, E. & Busk, G. (eds.). *Quarterly Journal of Microscopical Science*, 1857, vol. 5, (17), 13-16 (http://jcs.biologists.org/content/s1-5/17/13.full.pdf+html); (18), 90-96 (http://jcs.biologists.org/content/s1-5/18/90.full.pdf+html); (19), 143-149 (http://jcs.biologists.org/content/s1-5/19/143.full.pdf+html).
31. Siebold, C. Th. v. "Ueber einzellige Pflanzen und Thiere (On unicellular plants and animals) (http://www.biodiversitylibrary.org/item/49155#page/5/mode/1up)". In: Siebold, C. Th. v. & Kölliker, A. (1849). *Zeitschrift für wissenschaftliche Zoologie*, Bd. 1, p. 270. Translation at: Lankester, E. & Busk, G. (eds.). *Quarterly Journal of Microscopical Science*, 1853, vol. 1, (2), 111-121 (http://jcs.biologists.org/content/s1-1/2/111.full.pdf+html); (3), 195-206 (http://jcs.biologists.org/content/s1-1/3/195.full.pdf+html).
32. Williams, B. A.; Keeling, P. J. (2003). "Cryptic organelles in parasitic protists and fungi". In Littlewood, D. T. J. *The Evolution of Parasitism*. London: Elsevier Academic Press. p. 46. ISBN 0-12-031754-0.
33. Round (1981). pp. 398–400, [3] (https://books.google.com/books?id=Rm08AAAAIAAJ&lpg=PA262&hl=&pg=PA398).
34. Ivan Noble (18 September 2003). "When plants conquered land". BBC.
35. Wellman, C.H.; Osterloff, P.L.; Mohiuddin, U. (2003). "Fragments of the earliest land plants". *Nature*. **425** (6955): 282–285. Bibcode:2003Natur.425..282W. doi:10.1038/nature01884. PMID 13679913.
36. Xiao, S.; Knoll, A.H.; Yuan, X.; Pueschel, C.M. (2004). "Phosphatized multicellular algae in the Neoproterozoic Doushantuo Formation, China, and the early evolution of florideophyte red algae". *American Journal of Botany*. **91** (2): 214–227. doi:10.3732/ajb.91.2.214. PMID 21653378.
37. Waggoner, Ben (1994–2008). "Introduction to the Phaeophyta: Kelps and brown "Algae" ". University of California Museum of Palaeontology (UCMP). Archived from the original on 21 December 2008. Retrieved 19 December 2008.
38. Thomas, D N (2002). *Seaweeds*. London: The Natural History Museum. ISBN 978-0-565-09175-0.
39. Waggoner, Ben (1994–2008). "Introduction to the Rhodophyta, The red "algae" ". University of California Museum of Palaeontology (UCMP). Archived from the original on 18 December 2008. Retrieved 19 December 2008.
40. "Introduction to the Green Algae". *berkeley.edu*.
41. Tazawa, Masashi (2010). "Sixty Years Research with Characean Cells: Fascinating Material for Plant Cell Biology". *Progress in Botany*. Progress in Botany. Springer. **72**: 5–34. doi:10.1007/978-3-642-13145-5_1. ISBN 978-3-642-13145-5. Retrieved 7 October 2012.

42. Tarakhovskaya, E. R.; Maslov, Yu. I.; Shishova, M. F. (April 2007). "Phytohormones in algae". *Russian Journal of Plant Physiology*. **54** (2): 163–170. doi:10.1134/s1021443707020021.
43. Brodo, Irwin M; Sharnoff, Sylvia Duran; Sharnoff, Stephen; Laurie-Bourque, Susan (2001). *Lichens of North America*. New Haven: Yale University Press. p. 8. ISBN 978-0-300-08249-4.
44. Pearson, Lorentz C (1995). *The Diversity and Evolution of Plants*. CRC Press. p. 221. ISBN 978-0-8493-2483-3.
45. Brodo et al. (2001), page 6: "A species of lichen collected anywhere in its range has the same lichen-forming fungus and, generally, the same photobiont. (A particular photobiont, though, may associate with scores of different lichen fungi)."
46. Brodo et al. (2001), page 8.
47. Taylor, Dennis L (1983). "The coral-algal symbiosis". In Goff, Lynda J. *Algal Symbiosis: A Continuum of Interaction Strategies*. CUP Archive. pp. 19–20. ISBN 978-0-521-25541-7.
48. http://uwsp.edu/cnr/UWEXlakes/laketides/vol26-4/vol26-4.pdf
49. Frenkel J, Vyverman W, Pohnert G (2014). "Pheromone signaling during sexual reproduction in algae". *Plant J*. **79** (4): 632–44. doi:10.1111/tpj.12496. PMID 24597605.
50. Harris Bernstein, Carol Bernstein and Richard E. Michod (2011). Meiosis as an Evolutionary Adaptation for DNA Repair. Chapter 19 pages 357–382 in "DNA Repair" (Inna Kruman editor). InTech Open Publisher. DOI: 10.5772/25117 ISBN 978-953-307-697-3 http://www.intechopen.com/books/dna-repair/meiosis-as-an-evolutionary-adaptation-for-dna-repair
51. Otto SP (2009). "The evolutionary enigma of sex". *Am. Nat*. 174 Suppl 1: S1–S14. doi:10.1086/599084. PMID 19441962.
52. Heywood P, Magee PT (1976). "Meiosis in protists. Some structural and physiological aspects of meiosis in algae, fungi, and protozoa". *Bacteriol Rev*. **40** (1): 190–240. PMC 413949. PMID 773364.
53. "Algae Herbarium". National Museum of Natural History, Department of Botany. 2008. Archived from the original on 1 December 2008. Retrieved 19 December 2008.
54. John (2002), page 1.
55. Huisman (2000), page 25.
56. Stegenga (1997).
57. Clerck, Olivier (2005). *Guide to the seaweeds of KwaZulu-Natal*. ISBN 978-90-72619-64-8.
58. Abbott and Hollenberg (1976), page 2.
59. Hardy and Guiry (2006).
60. Guiry, M. D. (2012). "How Many Species of Algae Are There?". *Journal of Phycology*. **48** (5): 1057–1063. doi:10.1111/j.1529-8817.2012.01222.x. PMID 27011267.
61. Round, FE (1981). "Chapter 8, Dispersal, continuity and phytogeography". *The ecology of algae*. pp. 357–361. Retrieved 6 February 2015.
62. Round (1981), page 362.
63. Round (1981), Page 357.
64. Round (1981), page 371.
65. Round (1981), page 366.
66. Round (1981), page 176.
67. Wan Maznah Wan Omar (Dec 2010). "Perspectives on the Use of Algae as Biological Indicators for Monitoring and Protecting Aquatic Environments, with Special Reference to Malaysian Freshwater Ecosystems". *Trop Life Sci Res*. **21** (2): 51–67. PMC 3819078. PMID 24575199.
68. Necchi Jr., O. (ed.) (2016). *River Algae*. Springer, [4] (https://books.google.com/books?id=KptPDAAAQBAJ).
69. Johansen, J. R. 2012. Diatoms of aerial habitats. In: Smol, J. P. & Stoermer, E. F. (Eds.). *The Diatoms: Applications for the Environmental and Earth Sciences*, 2nd ed. Cambridge University Press. Cambridge, UK. pp. 465–472, [5] (https://books.google.com/books?id=SpuPKw7zZGAC&lpg=PP1&hl=&pg=PA465#v=onepage&q&f=false).
70. Sharma, O. P. (1986). pp. 2–6, [6] (https://books.google.com/books?id=hOa74Hm4zDIC&lpg=PP1&hl=&pg=PA2#v=onepage&q&f=false).
71. Lewis, J G; Stanley, N F; Guist, G G (1988). "9 Commercial production of algal hydrocolloides". In Lembi, C.A.; Waaland, J.R. *Algae and Human Affairs*. Cambridge: Cambridge University Press. ISBN 978-0-521-32115-0.
72. "Macrocystis C. Agardh 1820: 46". AlgaeBase. Retrieved 28 December 2008.

73. "Secondary Products of Brown Algae". *Algae Research*. Smithsonian National Museum of Natural History. Retrieved 29 December 2008.
74. Chisti, Y (May–Jun 2007). "Biodiesel from microalgae.". *Biotechnology advances*. **25** (3): 294–306. doi:10.1016/j.biotechadv.2007.02.001. PMID 17350212.
75. Yang, ZK; Niu, YF; Ma, YH; Xue, J; Zhang, MH; Yang, WD; Liu, JS; Lu, SH; Guan, Y; Li, HY (4 May 2013). "Molecular and cellular mechanisms of neutral lipid accumulation in diatom following nitrogen deprivation.". *Biotechnology for biofuels*. **6** (1): 67. doi:10.1186/1754-6834-6-67. PMC 3662598. PMID 23642220.
76. An Outlook on Microalgal Biofuels René H. Wijffels and Maria J. Barbosa Science 13 August 2010: 329 (5993), 796–799. [DOI:10.1126/science.1189003]
77. Read, Clare Sewell (1849). "On the Farming of South Wales: Prize Report". *Journal of the Royal Agricultural Society of England*. London: John Murray. **10**: 142–143. Downloadable Google Books (https://books.google.com/books?id=UJYEAAAAYAAJ&pg=PA142&dq=%22this+kind+of+ore+they+often+gather%22&lr=&as_brr=0&as_pt=ALLTYPES#PPR4,M1).
78. McHugh, Dennis J. (2003). "9, Other Uses of Seaweeds". *A Guide to the Seaweed Industry: FAO Fisheries Technical Paper 441*. Rome: Fisheries and Aquaculture Department, Food and Agriculture Organization (FAO) of the United Nations. ISBN 978-92-5-104958-7.
79. Simoons, Frederick J (1991). "6, Seaweeds and Other Algae". *Food in China: A Cultural and Historical Inquiry*. CRC Press. pp. 179–190. ISBN 978-0-936923-29-1.
80. Morton, Steve L. "Modern Uses of Cultivated Algae". *Ethnobotanical Leaflets*. Southern Illinois University Carbondale. Archived from the original on 23 December 2008. Retrieved 26 December 2008.
81. Mondragón, Jennifer; Mondragón, Jeff (2003). *Seaweeds of the Pacific Coast*. Monterey, California: Sea Challengers Publications. ISBN 978-0-930118-29-7.
82. "Durvillaea antarctica (Chamisso) Hariot". AlgaeBase.
83. Bigogno, C; I Khozin-Goldberg; S Boussiba; A Vonshak; Z Cohen (2002). "Lipid and fatty acid composition of the green oleaginous alga Parietochloris incisa, the richest plant source of arachidonic acid". *Phytochemistry*. **60** (5): 497–503. doi:10.1016/S0031-9422(02)00100-0. PMID 12052516.
84. Allison Aubrey (1 November 2007). "Morning Edition: Getting Brain Food Straight from the Source". National Public Radio.
85. Morrissey, J., M.S. Jones and V. Harriott (1988). "ReefBase :: Main Publications : Nutrient cycling in the Great Barrier Reef Aquarium - Proceedings of the 6th International Coral Reef Symposium, Australia". *reefbase.org*.
86. "Patent US4333263 - Algal turf scrubber". *google.com*.
87. Hydromentia Water Treatment Technologies (http://www.hydromentia.com/Products-Services/Algal-Turf-Scrubber/Product-Documentation/Assets/ATS-Technical-Brochure.pdf)
88. "ALGAL RESPONSE TO NUTRIENT ENRICHMENT IN FORESTED OLIGOTROPHIC STREAM - Veraart - 2008 - Journal of Phycology - Wiley Online Library". *wiley.com*.
89. "Algae: A Mean, Green Cleaning Machine". USDA Agricultural Research Service. 7 May 2010.
90. Cappitelli, Francesca; Sorlini, Claudia (2008). "Microorganisms Attack Synthetic Polymers in Items Representing Our Cultural Heritage". *Applied and Environmental Microbiology*. **74** (3): 564–569. doi:10.1128/AEM.01768-07. PMC 2227722. PMID 18065627.
91. Arad, Shoshana; Spharim, Ishai (1998). "Production of Valuable Products from Microalgae: An Emerging Agroindustry". In Altman, Arie. *Agricultural Biotechnology*. Books in Soils, Plants, and the Environment. **61**. CRC Press. p. 638. ISBN 978-0-8247-9439-2.
92. C. Rathbun; A. Doyle; T. Waterhouse (June 1994). "Measurement of Algal Chlorophylls and Carotenoids by HPLC" (PDF). *Joint Global Ocean Flux Study protocols*. Global Ocean Data Analysis Project. **13**: 91–96.
93. M. Latasa; R. Bidigare (1998). "A comparison of phytoplankton populations of the Arabian Sea during the Spring Intermonsoon and Southwest Monsoon of 1995 as described by HPLC-analyzed pigments". *Deep-Sea Research Part II*. Pergamon Press. **45** (10-11): 2133–2170. Bibcode:1998DSRII..45.2133L. doi:10.1016/S0967-0645(98)00066-6.

Bibliography

General

- Chapman, V.J. (1950). *Seaweeds and their Uses*. London: Methuen & Co. Ltd. ISBN 978-0-412-15740-0.
- Fritsch, F.E. (1935/1945). *The Structure and Reproduction of the Algae*. I. and II. Cambridge, England: Cambridge University Press
- van den Hoek, C., D.G. Mann, and H.M. Jahns (1995). *Algae: an introduction to phycology*. Cambridge University Press (623 pp).
- Lembi, C.A.; Waaland, J.R. (1988). *Algae and Human Affairs*. Cambridge: Cambridge University Press. ISBN 978-0-521-32115-0.
- Mumford, T F; Miura, A (1988). "*Porphyra* as food: cultivation and economic". In Lembi, C A; Waaland, J R. *Algae and Human Affairs*. Cambridge University Press. pp. 87–117. ISBN 978-0-521-32115-0..
- Round, F E (1981). *The Ecology of Algae*. London: Cambridge University Press. ISBN 978-0-521-22583-0.
- Smith, G.M. (1938). *Cryptogamic Botany*, vol. 1 (https://archive.org/details/cryptogamicbotan031880mbp). McGraw-Hill, New York.

Regional

Britain and Ireland

- Brodie, Juliet; Burrows, Elsie M; Chamberlain, Yvonne M.; Christensen, Tyge; Dixon, Peter Stanley; Fletcher, R.L.; Hommersand, Max H; Irvine, Linda M; et al. (1977–2003). *Seaweeds of the British Isles: A Collaborative Project of the British Phycological Society and the British Museum (Natural History)*. London, Andover: British Museum (Natural History), HMSO, Intercept. ISBN 978-0-565-00781-2.
- Cullinane, John P (1973). *Phycology of the South Coast of Ireland*. Cork: Cork University Press.
- Hardy, F G; Aspinall, R J (1988). *An Atlas of the Seaweeds of Northumberland and Durham*. The Hancock Museum, University Newcastle upon Tyne: Northumberland Biological Records Centre. ISBN 978-0-9509680-5-6.
- Hardy, F G; Guiry, Michael D; Arnold, Henry R (2006). *A Check-list and Atlas of the Seaweeds of Britain and Ireland* (Revised ed.). London: British Phycological Society. ISBN 978-3-906166-35-3.
- John, D M; Whitton, B A; Brook, J A (2002). *The Freshwater Algal Flora of the British Isles*. Cambridge, UK; New York: Cambridge University Press. ISBN 978-0-521-77051-4.
- Knight, Margery; Parke, Mary W (1931). *Manx Algae: An Algal Survey of the South End of the Isle of Man*. Liverpool Marine Biology Committee (LMBC) Memoirs on Typical British Marine Plants & Animals. **XXX**. Liverpool: University Press.
- Morton, Osborne (1994). *Marine Algae of Northern Ireland*. Belfast: Ulster Museum. ISBN 978-0-900761-28-7.
- Morton, Osborne (1 December 2003). "The Marine Macroalgae of County Donegal, Ireland". *Bulletin of the Irish Biogeographical Society*. **27**: 3–164.

Australia

- Huisman, J M (2000). *Marine Plants of Australia*. University of Western Australian (UWA) Press. ISBN 978-1-876268-33-6.

New Zealand

- Chapman, Valentine Jackson; Lindauer, VW; Aiken, M; Dromgoole, FI (1970) [1900, 1956, 1961, 1969]. *The Marine algae of New Zealand*. London; Lehre, Germany: Linnaean Society of London; Cramer.

Europe

- Cabioc'h, Jacqueline; Floc'h, Jean-Yves; Le Toquin, Alain; Boudouresque, Charles-François; Meinesz, Alexandre; Verlaque, Marc (1992). *Guide des algues des mers d'Europe: Manche/Atlantique-Méditerranée* (in French). Lausanne, Suisse: Delachaux et Niestlé. ISBN 978-2-603-00848-5.

- Gayral, Paulette (1966). *Les Algues de côtes françaises (manche et atlantique), notions fondamentales sur l'écologie, la biologie et la systématique des algues marines* (in French). Paris: Doin, Deren et Cie.
- Guiry, M.D.; Blunden, G. (1991). *Seaweed Resources in Europe: Uses and Potential*. John Wiley & Sons. ISBN 978-0-471-92947-5.
- Míguez Rodríguez, Luís (1998). *Algas mariñas de Galicia: bioloxía, gastronomía, industria* (in Galician). Vigo: Edicións Xerais de Galicia. ISBN 978-84-8302-263-4.
- Otero, J. (2002). *Guía das macroalgas de Galicia* (in Galician). A Coruña: Baía Edicións. ISBN 978-84-89803-22-0.
- Bárbara, I.; Cremades, J. (1993). *Guía de las algas del litoral gallego* (in Spanish). A Coruña: Concello da Coruña – Casa das Ciencias.

Arctic

- Kjellman, Frans Reinhold (1883). *The algae of the Arctic Sea: a survey of the species, together with an exposition of the general characters and the development of the flora*. **20**. Stockholm: Kungl. Svenska vetenskapsakademiens handlingar. pp. 1–350.

Greenland

- Lund, Søren Jensen (1959). *The Marine Algae of East Greenland*. Kövenhavn: C.A. Reitzel. 9584734.

Faroe Islands

- Børgesen, Frederik (1970) [1903]. "Marine Algae". In Warming, Eugene. *Botany of the Faröes Based Upon Danish Investigations. Part II*. København: Det nordiske Forlag. pp. 339–532..

Canary Islands

- Børgesen, Frederik (1936) [1925, 1926, 1927, 1929, 1930]. *Marine Algae from the Canary Islands*. København: Bianco Lunos.

Morocco

- Gayral, Paulette (1958). *Algues de la côte atlantique marocaine* (in French). Casablanca: Rabat [Société des sciences naturelles et physiques du Maroc].

South Africa

- Stegenga, H.; Bolton, J.J.; Anderson, R.J. (1997). *Seaweeds of the South African West Coast*. Bolus Herbarium, University of Cape Town. ISBN 978-0-7992-1793-3.

North America

- Abbott, I.A.; Hollenberg, G.J. (1976). *Marine Algae of California*. California: Stanford University Press. ISBN 978-0-8047-0867-8.
- Greeson, Phillip E. (1982). *An annotated key to the identification of commonly occurring and dominant genera of Algae observed in the Phytoplankton of the United States*. Washington, D.C.: US Department of the Interior, Geological Survey. Retrieved 19 December 2008.
- Taylor, William Randolph (1969) [1937, 1957, 1962]. *Marine Algae of the Northeastern Coast of North America*. Ann Arbor: University of Michigan Press. ISBN 978-0-472-04904-2.
- Wehr, J D; Sheath, R G (2003). *Freshwater Algae of North America: Ecology and Classification*. US: Academic Press. ISBN 978-0-12-741550-5.

External links

- Guiry, Michael and Wendy. "AlgaeBase". – a database of all algal names including images, nomenclature, taxonomy, distribution, bibliography, uses, extracts
- Algae – Cell Centered Database (http://ccdb.ucsd.edu/sand/main?stype=lite&keyword=algae&event=display&Submit=Go&start=1)

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- "Algae Research". National Museum of Natural History, Department of Botany. 2008. Archived from the original on 1 December 2008. Retrieved 19 December 2008.
- Anderson, Don; Bruce Keafer; Judy Kleindinst; Katie Shaughnessy; Katherine Joyce; Danielle Fino; Adam Shepherd (2007). "Harmful Algae". US National Office for Harmful Algal Blooms. Archived from the original on 5 December 2008. Retrieved 19 December 2008.
- "Australian Freshwater Algae (AFA)". Department of Environment and Climate Change NSW Botanic Gardens Trust. Archived from the original on 30 December 2008. Retrieved 19 December 2008.
- "Freshwater Algae Research". Phycology Section, Patrick Center for Environmental Research. 2011. Retrieved 17 December 2011.
- "Monterey Bay Flora". Monterey Bay Aquarium Research Institute (MBARI). 1996–2008. Retrieved 20 December 2008.
- Silva, Paul (1997–2004). "Index Nominum Algarum (INA)". Berkeley: University Herbarium, University of California. Archived from the original on 23 December 2008. Retrieved 19 December 2008.
- Algae: Protists with Chloroplasts (http://tolweb.org/notes/?note_id=52)
- "Research on microalgae". Wageningen UR. 2009. Archived from the original on 24 April 2009. Retrieved 18 May 2009.
- Algae glossary (Australian Biological Resources Study). (http://www.environment.gov.au/biodiversity/abrs/online-resources/glossaries/algae/index.html)
- "About Algae". Natural History Museum, United Kingdom.
- EnAlgae [7] (http://www.enalgae.eu)

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