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Introduction

Brown algae or class Phaeophyceae (Fritsch 1945) along with diatoms and oomycetes belong to a group called **heterokonts** (Anderson 2004)'. They are very distantly related to their counterparts, green and red algae (Baldauf 2003). A large group of mostly marine, multicellular algae, Phaeophyceae is seen along rocky shores and in shallow waters typically attached to rocks or substratum of colder Northern hemisphere waters (*Fucus* sp) while a few 'browns' such as *Sargassum* sp and members of Dictyotales are tropical warm water inhabitants. Only seven species are fresh water inhabitants, e.g., *Heribaudiella fluviatilis*, *Sphacelaria fluviatilis*, *Pleurocladia lacustris*, *Porterinema fluviatilis*, *Ectocarpus siliculosus* and *Bodanella lauterborni* (Linda et al 2007). However, some are brackish water (*Fucus vesiculosus*) and saline water inhabitants. One of the brown seaweeds *Pelvetia* is known to 'shun' water (Rugg and Norton 1987) and if left submerged for more than six hours out of twelve, it begins to decay.

Range of thallus

Brown algae exist in a wide range and forms where the smallest members of the group appear as tiny feathery tufts of thread-like cells, a few cms long e.g., *Ectocarpus.* Other brown algae, like rockweeds (*Fucus* sp) and leathery kelps are conspicuous in waters due to their size which ranges from 2 feet tall sea palm *Postelsia* to the giant kelp *Macrocystis pyrifera* which grows over 45 m long and is the largest known alga.

Figure: The 'Browns'

A. *Ectocarpus*, belonging to Ectocarpales has the simplest thallus amongst the browns which in most of the species is feather-like. Source: http://upload.wikimedia.org/wikipedia/commons/a/a6/Ectocarpus_siliculosus_Crouan_%282%29.jpg

B. *Padina* belonging to Dictyotales has a fan-like leafy thallus. The hairs and the sori are borne in rings.
Source:http://calphotos.berkeley.edu/imgs/512x768/4444_4444/0311/6607.jpeg

C. *Pelvetia canaliculata*, belonging to Fucales is an upshore species and is known to shun water. Source: http://upload.wikimedia.org/wikipedia/commons/c/c4/Pelvetia_canaliculata.jpg

D. *Dictyota*, from Dictyotales shows a dichotomously branched thallus with growth occurring at each frond tip. Source: http://upload.wikimedia.org/wikipedia/commons/thumb/0/0b/Capo_Gallo_Dicotoma.jpg/220px-Capo_Gallo_Dicotoma.jpg

E. *Sargassum muticum*, a fucalean commonly known as gulf wrack shows an angiosperm-like stem and leaves. Air bladders or pneumatocysts help the plant stay afloat.

Source: http://3.bp.blogspot.com/_HEkoxfFADrM/S76du0p7g6I/AAAAAAAAE3s/UU5uBriYCDw/s400/sargasso.jpg

Considering the body plan, the members may range from uniseriate branched filaments to pseudoparenchymatous (or **haplosticous**) to complex parenchymatous thalli with multiple cell types (**polystichous**) (Lee1999). In polystichous construction the cell types include special meristematic tissue (meristoderm in Fucales) and conducting tissues (trumpet hyphae in Laminariales). They may also form small crusts (*Lobophora*) and cushions and also occur as leafy free floating mats formed by *Sargassum* sp. Delicate felt-like strands as in *Ectocarpus* and foot-long flattened thalli resembling a fan as in *Padina* are also some of the expressions of Phaeophycean morphology. Algae like *Sargassum muticum*, *Undaria pinnatifida* and *Turbinaria ornata* are considered to be amongst important invasive brown seaweeds.

Characteristic features

A few features set Phaeophyceae apart from all other algae. These are:

- The members possess a characteristic colour ranging from an olive green and passing through various shades of brown. The particular shade depends upon the amount of photosynthetic pigment- **fucoxanthin** present in the plastids. Besides fucoxanthin, these algae contain beta-carotene and chlorophyll a and c as the photosynthetic pigments.
- All brown algae are multicellular and are the only group of seaweeds which does not have members that are either single celled or colonial.
- The cell wall has cellulose and alginates, latter comprising a larger proportion along with fucoidans, the sulphated polysaccharides. Alginates are non toxic salts of alginic acids (Li et al 2008) and are used to stabilize emulsions and suspensions. Both these phycocolloids from brown algae have great industrial application (Se Kwon Kim 2013, Balch 1992).
- The cells lack true starch as reserve food but have **laminarin**; the transport form commonly being **mannitol**.
- Growth in most brown algae occurs as a result of apical cell activity concentrated towards the tips. However, a few forms like *Ectocarpus* grow by a diffuse unlocalized growth in which new cells are formed anywhere on the thallus. *Laminaria*, shows formation of annual growth rings, the phenomenon resembling stem growth in higher plants. Concentric rings are visible in cross section of the **stipe** of *Laminaria* sp. The deposition of secondary cortex resulting in formation of these rings is

demonstrated to be an annual phenomenon and consequently stipe ring number can be used to determine individual age (Klinger et al 1988).

- Whatever their form of growth, the body organization in all brown algae is **thallus** type indicating absence of xylem and phloem from the tissue plan. Holdfast is a root- like structure which serves to anchor the alga firmly in the substratum as well as helps in regeneration (as in *Sargassum*). The highly branched disc may lead to formation of **haptera** as in kelps and some fucoids like *Turbinaria*. Stipe or stalk or stem-like structure may be short remain undivided (as in *Laminaria*) or may develop into a large complex branched structure running through out (as in *Sargassum*). Many members have a flattened portion arising from stipe/stem that may resemble leaf and this has been variously referred to as blade, lamina or frond. In many species lamina has a midrib and wings; blades are often also the sex bearing parts of the alga.
- The thalli show three distinct regions of tissue organization--- central medulla, middle cortex and outermost **meristoderm**. In *Laminaria* phloem-like cells known as trumpet cells are seen in the medulla. The higher forms belonging to Laminariales and Fucales have air bladders or pneumatocysts which make the thallus buoyant. The only exception is seen in *Pelvetia* which does not have air bladders and grows on rocks forming uppermost zone of algae.
- The plastids of brown algae may be disc-like, parietal or stellate in shape. The plastid is enveloped by two unit membranes, the inner and outer chloroplast membrane. In addition to this, there are two additional membranes that form the chloroplast endoplasmic reticulum which maintains continuity with the outer envelope of the nucleus. Phaeophycean plastids have three thylakoids per lamella and a girdle lamella near chloroplast envelope. Pyrenoids are commonly seen in some orders (e.g., Ectocarpales) and are poorly developed in others (Fucales).
- Physodes, the **phlorotannin** containing vacuoles perform a number of ecological functions like deterring herbivores, healing the wounds, acting as a shield against intense sunlight and are also responsible for dark brown discolouration of the decayed alga.
- Many brown algae especially the kelps, concentrate iodine in their cells. They also release large quantities of volatile brominated methane into the atmosphere and are linked to the current environmental issues (Turan and Neori 2010).
- Reproduction is highly evolved in Phaeophyceae with advanced orders exhibiting great adaptation for intertidal gamete release, gamete union and propagule

dispersal. All the three modes of reproduction : vegetative, asexual and sexual are met with. Populations in brackish waters however, have almost totally lost their ability to reproduce sexually and their primary method to reproduce is vegetative. Some like *Dictyota dichotoma* have successfully propagated asexually through fragments created by biotic and abiotic stress. The drift plants of another invasive alga *Sargassum muticum* are fertile with androgynous conceptacles resulting in higher rates of reproduction while the alga is afloat. (htpp://www.doeni.gov.uk/niea/*sargassum*/pdf).

During the long period of evolutionary time scale, brown algae have evolved many unusual characteristics that are not found in the other groups, and these include a number of features that have exquisitely adapted these organisms for the harsh environment of intertidal and subtidal zones. These are given below:

Endosymbiosis and origin of chloroplasts----The chloroplasts of heterokonts such as brown algae have a more complicated origin. The plastids have four concentric membranes and the plastids have been acquired via a process of secondary endosymbiosis involving the capture of red alga (Archibald 2012).

Complex multicellularity----The Phaeophyceae are one of the five eukaryotic groups (the other four being animals, green plants/algae, fungi and red algae) to have evolved complex multicellularity, a feature that has arisen rarely during evolution (Cock et al 2010).

Life cycles and mating types----In addition to a complex multicellular organisation, brown algae exhibit several distinctive life cycles and mating behaviours. Life cycles range from nearly isomorphic(where haploid and diploid phases are morphologically similar) life cycle of *Ectocarpus* to diplontic animal-like in *Fucus.* Some members such as *Laminaria* show heteromorphic alternation of generations. The members show both **dioecious** and **monoecious** states and gametes may range from **isogamous** to **anisogamous** in lower forms as in *Ectocarpus* to oogamous in advanced fucalean members (Graham and Wilcox 2000). The phenomenon of pheromone action and gamete union is highly advanced in various members.

Early embryogenesis----Fertilization is external and involves union of naked gametes that are released into the surrounding seawater. This feature has been exploited widely to study events in early development including gamete fusion at fertilization, establishment of zygote polarity, the involvement of cell walls in early developmental signalling, embarking on first cell cycle, coupling between cell cycle and developmental processes and other aspects of embryogenesis (Berger et al 1994, Corellou et al 2001).

Response to biotic and abiotic stress----The brown algae represent novel model systems for several aspects of responses to biotic (from grazers and pathogens) and abiotic stress (variation in temperature, immersion, light, wave action and other mechanical forces like grazing). Also included are studies on innate immunity (Potin et al 2002), and novel pathosystems (Maier et al 2000).

Genetic regulation---- Life cycles like that of *Ectocarpus* generate interest because they indicate the existence of genetic control involved in mechanisms that regulate deployment of the two alternative, independent (haploid and diploid) developmental programmes, influencing whole organism development. Fucales and Laminariales have been extensively investigated in the past, but due to the large genome size (700 and 1100 Mbp respectively) have been found to be poorly adapted for genomic and genetic approaches. *Ectocarpus siliculosus* on the contrary because of small genome size, short life cycle that be completed in the petri dishes (Müller et al 1998), its high fertility and rapid growth (life cycle can be completed in 2-3 months), and the ease with which genetic crosses can be made (Peters et al 2004).is the preferred model being studied. These studies have given impetus to brown algal research that has not only provided insight into specific biological processes, but also yielded information about the brown algal evolution which has occurred over the ages evolving them into complex multicellular organisms (http://www.vib.be/en/about-vib/annual-eport/2011/research/Pages/The*Ectocarpus* genome yields information about the evolution of brown algae)

Economic Importance

Phaeophyceae are the key primary producers in intertidal shallow and deep subtidal reefs. Some like *Undaria pinnatifida*, *Turbinaria ornata* and *Sargassum muticum* have become invasive and are known to pose threat to native species and also grow over and smother coral reef and native algal communities, killing extensive areas of native habitat (http://malamamaunalua.org/problems/problems-science-invasive-algae/). Almost all members play an important role, both as food and as habitat for a large number of other marine organisms. For instance, *Macrocystis*, the giant kelp is known to form prominent underwater forests supporting a great biodiversity under the canopies. Another example is *Sargassum* which creates thick forests in the tropical waters of the Sargasso Sea in which thrive a set of organisms.

Figure A-G. Seaweed applications

A. Maxicrop, an organic fertilizer from *Ascophyllum nodosum*, can be used on the entire lawn besides bulbs and cuttings. http://www.organic-gardening-shop.com/Agorganics/Images/FullImage/MX001MX002.jpg
B. Alga grand a popular liquid fertilizer with growth hormones, amino acids and nutrients for self-protection. http://www.liquidfertilizerorganic.com/wp-content/uploads/2011/03/LIQUID-KELP-FERTILIZER-ORGANIC-AGGRAND.jpg
C. Wakame salad from *Undaria* is common in USA and Asia. http://upload.wikimedia.org/wikipedia/commons/thumb/f/f9/Boiled_wakame.jpg/220px-Boiled_wakame.jpg
D. Seaweed biscuits, the nutraceuticals. http://3.bp.blogspot.com/_cuENz-xNstE/TUbfNtQ73bI/AAAAAAAABik/dZ_1Gi0ItCQ/s1600/310120111867.jpg
E. Seaweeds have a number of applications by virtue of their medicinal value, the pharmaceuticals. http://www.tennis.com/your-game/2012/09/superfoods/39552/
F. Thalasso therapy—seaweed body wrap gives 'beautiful you', the cosmaceutical. http://s3-media2.ak.yelpcdn.com/bphoto/XS-67PU2R1QPua8xha48FQ/o.jpg
G. Combating global warming with seaweeds. http://www.cepp.utm.my/rcentre/files/Seaweed.jpg

The Browns form an important pillar of multibillion dollar seaweed industry. They find a wide range of uses in food, cosmetics and fertilizer industry. The members are widely used as

Seaweed Liquid Fertilizers (SLF) and are applied as foliar sprays and root drench. This has led to setting up of seaweed fertilizer industry in many European and Asian countries. The health benefits of browns are also immense and in recent times they are recommended as **nutraceuticals** and food supplements. They have become popular sea vegetables like kombu (*Laminaria* sp), and wakame (*Undaria*) are common brown sea vegetables. Brown algae are the only plant source of thyroid hormones and are included in diet for the iodine content. The regular kombu consumption as advised by the nutraceutical companies is believed to help in improving coronary artery disease, bring healthier liver function and faster food transmit time in digestive tract. The macro algae consumed as sea vegetables contain levels of fibre that are comparable to the vegetables. Laminaria digitata contains 6.2% fibre higher than that contained in prunes, apples and banana with same weight. Algin obtained from the walls of brown algae is generally not digestible but has a great potential as heavy metal detoxifying agent. When added to the diet as algin powder, it can bind heavy metals present in the food steam and remove them out with the stool. In the cosmetic industry they are being widely used in **thallasotherapy (a form of external macro algal treatment is an ageless, health restorative technique).** A mineral rich blend of seaweed extracts and sea salt crystals that hydrate and soften the skin is being used world over. Besides this brown algae are popular in, spa and face packs to detox the body system and have a great application in anti ageing creams, shampoos and gels (Vijayaraghavan and Kaur 1997). The brown seaweeds are also implicated in cutting down green house effect. Highly productive seaweed species can contribute significantly to the annual biological drawdown of CO_2 and the global carbon cycle (Turan and Neori 2010). They are increasingly gaining attention as a novel source of bioactive molecules. IODUS 40, a formulation known to stimulate natural defense response of crop plants.is derived from a storage glucan of *Laminaria digitata.* The characteristic secondary metabolites namely diterpenes, phlorotannins and small C 11 acetogenins have industrial applications (Blaut et al 2007).

PONDER OVER

Seaweed beds can serve as a significant carbon dioxide (CO_2) sink while also satisfying global needs for food, fodder, fuel, and pharmaceutical products. Using innovative research approaches, Korean scientists have established the Coastal CO_2 Removal Belt (CCRB), which comprises both natural and man-made plant communities in the coastal region of southern Korea. Implemented on various spatial–temporal scales, this scheme promotes the removal of CO_2 via marine forests. For example, when populated with the perennial brown alga *Ecklonia*, a pilot CCRB farm can draw down ~10 t of CO_2 per ha per year. This success is

manifested by an increment in biomass accumulations and a decrease in the amount of dissolved inorganic carbon in the water column (Turan and Neori 2010).

Due to the wide applications of this group of algae, their demand in global market has increased many folds and they are now said to form a multi million dollar industry. The overexploitation of these seaweeds has threatened the very existence of this marine resource. Researchers all over the globe are experimenting to increase the quality of the brown 'sea vegetables' through genetic engineering and also trying to meet the demand by carrying out **mariculture** of the seaweeds (Vijayaraghavan and Kaur 1997).

According to Fritsch (1945), there are nine orders:

Ectocarpales
Tilopteridales
Cutleriales
Sporochnales
Desmarestiales
Laminariales (commonly known as KELPS)
Sphacelariales
Dictyotales
Fucales

The Unique Identity (UID) of kelps

Image: The giant Kelps

Source : http://vintageprintable.com/wordpress/wp-content/uploads/2010/08/Botanical-Kelp-178x300.jpg

"Kelp" commonly refers to seaweeds of the brown algal order Laminariales, having large flat, leaflike fronds, a root-like holdfast also known as hapteron, and a flexible stipe (stem-like portion), and blades (flattened expansions often resembling leaves). The life cycle of the kelp shows alternation of a large spore-producing tough leathery stage (the sporophyte) and a microscopic gamete-producing stage (the gametophyte). Most of the kelps are found in the Pacific Ocean, while a restricted number occupies the Atlantic waters. They are well-adjusted for cold waters where they usually dominate the lower intertidal and upper subtidal floras. Dense growth of kelps results in Kelp forests that constitute important marine ecosystems in coastal areas of the world, and can support important commercial and recreational fisheries. Several species of kelp are considered economically important and have also been employed in western folk medicine. Until very recently, however, there has been limited evidence of pharmacological value, aside from the effects of compensating for iodine deficiency. Kelp tablets and powders have become popular herbal preparations in North America, and claims have been made that kelp products are useful in treating a variety of ailments. The therapeutic properties of kelp have been attributed particularly to the trace minerals, especially iodine, which is typically 20,000 times as concentrated in the seaweed by comparison with its aquatic habitat. The very high iodine content of brown algae led to their use in goiter medicines, but the variability of concentrations and the varying absorption conditions for bound and unbound iodine in the plant has made such algal therapy obsolete. Another interesting medical application is based on the ability of the dried stipes of *Laminaria* to expand their original circumference 3-5 times on wetting. These dried stipes have been used to produce non-instrument mechanical dilation of the cervical canal during birth and gynaecological treatment.

Although kelps are thought to inhibit heavy metal absorption in humans, those growing in polluted waters may accumulate very high levels of heavy metals especially arsenic. It is therefore important that while collecting kelps for commercial purposes they are collected from non-polluted waters.

Kelps reach great height and have very well developed holdfasts or **haptera** that grip onto rocky substrates. Kelps grow from the meristematic zone lying at the junction between the stipe and the lamina. Air bladders called **pneumatocysts**, are very well developed in kelps and help the plants keep afloat. A giant kelp plant has a pneumatocyst at the base of each blade. In contrast, bull kelp, *Nerocystis* has only one pneumatocyst supporting several

blades near the water surface. Due to their unique size and growth pattern, kelps are known to form dense canopies or kelp forests in the sea. *Macrocystis pyrifera* one of the fastest-growing plants on Earth, can grow at a rate of two feet a day reaching over 45 metres (148 ft) long in one growing season resulting in dense canopies in southern California.

Figure A-D. Kelps

A. *Macrocyctis pyrifera*, known to form sea forest in southern California is the giant kelp with growth rates more than those of the bamboo.
Source: http://content62.eol.org/content/2012/02/02/03/75842_580_360.jpg

B. *Laminaria* has a root-like holdfast, a divided blade and stem-like stipe connecting the blade to the holdfast. Source:
http://upload.wikimedia.org/wikipedia/commons/thumb/0/03/Laminaria_hyperborea.jpg/1024px-Laminaria_hyperborea.jpg

C. & D. *Nereocystis leutkeana* , the bull kelp has a well developed holdfast called haptera which may be referred to as root fingers. The kelp attaches itself to a hard substrate with haptera which also provides shelter for many invertebrate species. It has only one pneumatocyst that keeps several blades afloat.

Source: http://cfb.unh.edu/phycokey/Choices/Fucophyceae/NEREOCYSTIS/Nereocystis_01_500x375_.jpg, http://cfb.unh.edu/phycokey/Choices/Fucophyceae/NEREOCYSTIS/Nereocystis_09_600x400_luetkeana.jpg

E. *Postelsia sp.*, Common name Sea palm, has an upper end of stipe crowned with an array of drooping strap-like blades resemble miniature palms. Source: http://farm3.static.flickr.com/2362/1781861280_42b932f006.jpg

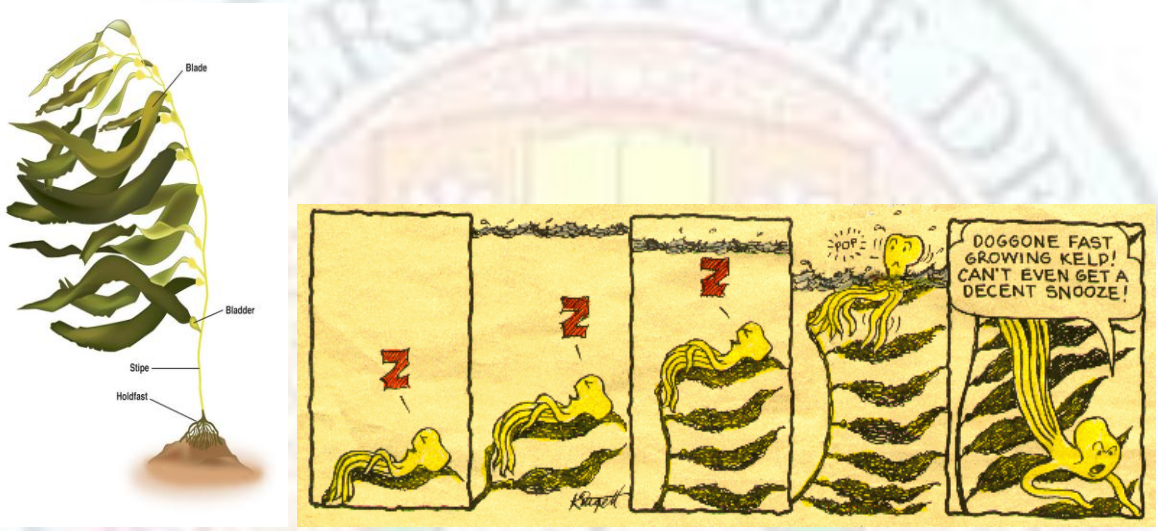

Figure: The giant kelp of the California coast is one of the fastest growing plant on land or sea, according to research conducted by The University of California's Institute of Marine Resources. This plant grows up from haptera on the sea floor to the water surface, where its long fronds spread out to form a dense, floating canopy bearing a resemblance to a forest. Length increases of twenty inches per day (10 to 15 feet per week) have been observed.
Source: http://microbewiki.kenyon.edu/images/4/41/Kelp_cartoon.gif

Such canopies are one of the most productive and dynamic ecosystems on the earth. They are known to give protection and provide food to many sea animals besides protecting the coastline from damaging wave action. In early times when civilizations in America were coming up, kelps were believed to have provided benefits to the boaters and the fishing communities, besides protecting them from rough waters by acting as a 'highway'. The kelp forests are now fast deteriorating due to water pollution and loss of biodiversity. Overfishing near shore ecosystems has led to the degradation of kelp forests. Herbivores are released from their usual population regulation, leading to over-grazing of kelp and other algae (Dayton 1985, Sala et al 1998). In one of the cases, kelps are known to be

affected by heavy grazing by sea animals like sea urchins leading to a great degree of damage. On the other hand, sea otter's favourite food is the sea urchin. When present in good numbers, sea otters keep sea urchin populations in check. But when sea otters decline, urchin numbers explode and they are free to chew off the haptera, leading to death of the holdfast and floating away of broken thalli. This upsets the life under canopy. By the early 20th century kelp beds in Central California started to disappear along with the marine life that they sustained. Realizing the benefits of kelps and kelp forests the government made several efforts towards protecting and conserving them. Efforts included checking further degradation of these ecosystems by moving remaining otters to Central California. This led to increase in the number of sea otters which brought down the number of sea urchin, and the kelp began growing again. As the underwater forests grew, other species reappeared and biodiversity once again improved.
For details visit: http://sanctuaries.noaa.gov/about/ecosystems/kelpdesc.html

Summary

Brown algae or Phaeophceae belong to a large group, the Heterokontophyta. The salient features are chromoplasts surrounded by four membranes. Most brown algae contain the pigment fucoxanthin responsible for the distinctive greenish-brown color of the seaweed. Besides fucoxanthin, chlorophyll a and c are the photosynthetic pigments. Brown algae are unique among heterokonts in developing into multicellular forms with highly differentiated tissues. However they reproduce by means of flagellated spores and gametes that closely resemble other heterokonts. The brown algae include the largest and fastest growing seaweeds, the kelps and the highly evolved group with animal like life cycle, the fucoids.

Algin from kelp and fucoids is a useful bulk demulcent (soothing) laxative. Fucoidans from kelp and fucoids are sulfated polysaccharides, known to be of use as antithrombin, anticancer and anticoagulant agents. Calcium and magnesium, both desirable as nutritional electrolytes, have been found to be very high in some commercial kelp preparations.With lot of commercial value attached to the brown algae attempts are being made world over to create marine sanctuaries with the aim of preserving and conserving this marine resource.

Exercises

Answer the following questions:

1. Give the salient features of Phaeophyceae.
2. Brown algae form a multimillion dollar industry. Comment.
3. Enumerate the features of brown algae which make them the most evolved group.
4. Draw well labeled neat diagrams of:
    a) V.S. of Chromoplast of brown alga
    b) Depict the morphology of a kelp
5. Fill in the blanks:
    a) The largest brown alga is _____.
    b) The reserve food material found in brown algae is_____.
    c) Sargasso sea is found in .
    d) _____ is an invasive brown weed.
    e) The unique mode of kelps is due to_____.
6. Match the following:

Column A	Column B
1. *Undaria*	a)Healing therapy
2. Giant kelp	b)Phenol-containing vacuoles
3. Physodes	c)Macrocystis
4. Thalassotherapy	d)Fresh water form
5. *Bodeniella*	e)Sea vegetable
	f)Seaweed liquid fertilizer

Glossary

Heterokont: Any eukaryote in this case alga, belonging to phylum Heterokontophyta and possessing two unequal flagella.

Haplostichous: Thallus construction, having free or loose filaments with no signs of intercalary, longitudinal cell divisions.

Polystichous: In certain Phaeophyceae, thallus construction is truly parenchymatous.

Fucoxanthin: In Phaeophyceae, (and also in Bacillariophyceae and Haptophyta), it is the predominant photosynthetic pigment responsible for olive green-brown colour of the thallus.

Laminarin: A soluble branched polysaccharide composed of β-l,3-linked glucans with some β-l,6-linkages, and is the main storage product of brown algae.

Mannitol: A polyhydroxyalcohol derived from the monosaccharide mannose is a form of carbohydrate transported in brown algal cells and has lot of commercial value.

Stipe: A stalk between the holdfast and the blade or frond of a fucoids and kelps thallii.

Thallus: The algal body (and that of thallophytes) simply constructed, and undifferentiated into root, stem and leaves (as seen in higher plants).

Hapteron: Derived from Greek word haptein is a branched robust holdfast very well developed in kelps and some fucoids.

Meristoderm: The outermost tissue at the surface of a thallus (i.e. an epidermis) of fucoid and kelp thallus which behaves meristematically, i.e. in which the cells divide frequently.

Phlorotannins: In Phaeophyceae, polymers of phloroglucinol (1,3,5-trihydroxybenzene) which exhibit the properties of tannins, precipitating proteins from solution and binding metal ions; with an astringent taste are stored in vacuoles known as physodes.

Isomorphic: Having gametophyte and sporophyte phases of similar (or identical) morphology and therefore difficult to differentiate.

Isogamy: Union of isogametes, wherein the gametes are identical with respect to shape, size and motility.

Dioecious: A condition in which the male and female gametes are produced on different individuals.

Monoecious: A condition in which male and female gametes are produced on the same individual.

Nutraceuticals: The term is applied to products that range from isolated nutrients, dietary and herbal products, specific diets, genetically modified foods, and processed foods such as cereals, soups, and beverages and are meant to supplement the main diet.

Mariculture: It is a specialized branch of aquaculture where cultivation of marine organisms for food and other products in the open ocean, an enclosed section of the ocean, or in tanks, ponds or raceways which are filled with seawater is carried out. In fact similar culture of seaweeds is now referred to as algaculture.

Hydrotherapy: Formerly called **hydropathy**, is a part of medicine and also branch of cosmetology, in particular of occupational therapy and physiotherapy, that involves the use of water for pain relief and treatment.

Thalassotherapy: (from the Greek word *thalassa*, meaning "sea") is the medical use of seawater, sea products, and shore climate as a form of therapy and believed to have beneficial effects upon the pores of the skin.

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