Contents:

Note # 1. Definition of Lichens:

A lichen can be defined as a structurally-organized entity consisting of the permanent association of a fungus and an alga. The lichens are commonly taken as a distinct group, though each one is a self-supporting intimate association of a fungus and an alga.

Note # 2. History of Lichenology:

Examination of lichen literature takes us back to Theophrastus, the disciple of Plato and Aristotle, who lived from 371 to 284 B.c., and who in his History of Plants used the term ‘lichen’, a word of Greek origin, to signify a superficial growth on the bark of olive trees.

Among the plants described by Theophrastus, there are evidently two lichens, one of which is either an Usnea or an Alectoria, and the other certainly Roccella tinctoria, the last-named economically important lichen is likely to be well-known for is valuable dyeing properties. The same or somewhat similar lichens are also referred to by the Greek physician Dioscorides, in his work on Materia Medica, A.d. 68.

During the centuries that followed, there was little study of lichens. In the sixteenth century there was a great awakening of scientific interest all over Europe. After the printing-press had come into general use, a number of books on Botany were published. The study of plants was at first entirely from a medicinal standpoint.

One of the herbs recommended for various ailments at that time is ‘Muscus arborum’, the tree-moss (Usnea). In addition to the tree-moss, several species of reputed value in the art of healing now known as Sticta (Lobaria) pulmonaria, Lobaria, laetevirens, Caldonia pyxidtta, Evernia prunasiri and Cetraria islandica were also described.

Lichen literature started increasing in volume in subsequent centuries as more and more people got interested in this line. Mention should be made of the name of Wallroth (1825), who first described and delimited the elements composing the lichen thallus.

Modern lichenology begins with the enunciation of Schwendener’s theory (1867) of the composite nature of the lichen. Schwendener’s announcement of dual hypothesis, that is, two organisms (an alga and a fungus) of independent origin were combined in the lichen, was not universally accepted. It was indeed bitterly and scornfully rejected by some of the prominent lichenologists of the time.

Schwendener held that the lichen was a fungus parasitic on an alga. His opponents considered such a view as wholly inadequate to explain the biology of lichens. It was not till a later date that the truer conception of the ‘symbiosis’ was proposed.

Systematic literature on lichens has been enriched in course of time by a series of important monographs, they are too numerous to mention here. The publication of the volume dealing with Lichens in Engler and Prantl’s Pflanzenfamilien has been a boon to those interested in lichens.

Note # 3. Origin of Lichens:

Though lichens are very old members of the plant kingdom, their origin is from a time subsequent to the evolution of their components. The algal components which belong to the Myxophyceae and Chlorophyceae had become aerial before their association with fungi to form lichens.

It is unnecessary to look for the algae as their ancestors as algae have persisted through ages in the same form in the lichen thalli. In the condition of lichen thalli they may be considerably modified, but they revert to their normal form, and assume their normal life history of spore production, etc., under suitable and free culture.

The fungus being the dominant partner, the principal line of development must be traced through it, as it provides the reproductive organs of the lichen thallus.

Though lichens have no common origin, the manner of life is common to them all and has influenced them all in certain directions. They are fitted for a much longer existence than that of the fungi from which they started.

In any case, great changes have taken place after relationship with algae became established. In respect of their fungal constituents lichens are also polyphyletic, and more especially in the Ascolichens which can be traced back to several starting points.

Whether there has been a series of origins within the different groups or a development from one starting point in each, it would be difficult to determine. The formation of lichen-acids which are excreted by the fungus is rather a noteworthy feature of the lichens. These substances are peculiar to lichens and go far to mark their autonomy.

The production of the acids and the many changes evolved in the vegetative thallus suggest the great antiquity of lichens.

The Basidiolichens are of comparatively recent origin, since the fungi belonging to the Basidiomycetes had, in the course of time, become less labile and less capable of originating a new method of existence. They lag immeasurably behind the Ascomycetes in the formation of lichens.

Note # 4. Distribution of Lichens:

The distribution of all lichens over the surface of the earth is controlled by climate and substratum. Though so numerous and so widely distributed, lichens have not evolved that great variety of families and genera characteristic to the allied fungi and algae. Study of the distribution of lichens reveals that certain families are more abundant in some regions than others, but, in general, nearly all are represented.

Certain species are universal, where similar conditions prevail. Although they do not usually form a conspicuous part of the vegetation, except in high mountain elevations, in the arctic tundras, in desert regions, and in many other environments where conditions are unfavourable for the growth of other types of plants, lichens play important roles in nature and in human life.

In arctic regions they develop as cushion-like masses on the ground, and because of the lack of competition of other plants they become an important part of the flora. In India, lichens are very common in the Eastern Himalayas with an annual rainfall of approximately 83 cm, than in the Western Himalayas where the rainfall is much less.

Note # 5. Habit and Habitat of Lichens:

Lichens are widely distributed on every convenient and in varied habitats. Many of them are able to grow in situations where no other plants could survive.

Consequently they are usually the pioneers in a succession of plants beginning in a habitat of bare rocks or a severely burnt-over area. Lichens are found growing on the leaves, the bark of trees (Fig. 313), especially on the shaded sides; on decaying wood, on rocks and on the soil.

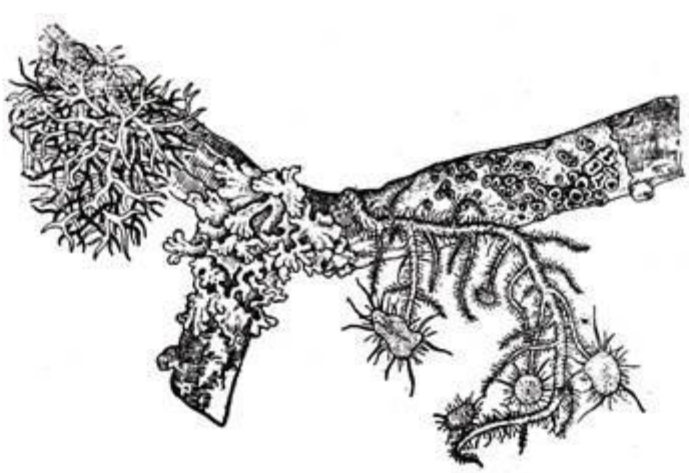

Fig. 313. Lichens growing on bark of tree twig.

They are adapted to survival under great extremes of heat, cold, and drought. In damp forests of warm regions, they often hang from the sides of trees often superficially resembling mosses.

A very few species of lichens develop in aquatic habitats. Lichens are resistant to extremes of temperatures, and their very slow growth rate (less than one millimetre per year for most mature crusts on boulders) enables them to tolerate habitats where the supply of mineral nutrients is low. They also withstand long periods of desiccation.

They tolerate frequent cycles of wetting and drying which is a positive requirement for healthy growth.

Note # 6. Ecology of Lichens:

The climatic factors most favourable to the development of lichens are: direct light, a moderate or cold temperature, constant moisture and a clear pure atmosphere. The development and distribution of lichens are so intimately associated with their habitat that it often surpasses all other ecological factors. Hence maximum importance is given to the habitat.

On the basis of habitat, lichen communities fall into the following categories:

1. Arboreal, those that grow on leaves, bark or wood.

2. Terricolous, ground-lichens.

3. Saaicolous, rock-lichens.

4. Omnicolous, lichens that can exist on the most varied substrata, such as bones, leather, iron, etc.

5. Localized communities, those responding very readily to special environments, and associations arise either of species met with elsewhere or of species restricted to one type of surroundings.

Note # 7. Classification of Lichens:

Since the time when lichens were first recognised as a separate class, many schemes of classification have been outlined and attempts were made to understand their puzzling structure.

Linnaeus (1753) classified them among algae under the general name Lichen, dividing them into eight orders based on the character of their thalli.

Mention may be made about the classification of Acharius (1803), who along with the form of the thalli also introduced the fundamental differences in fruiting structures of the lichen thalli.

Rcinke in 1896 published a classification system which may be briefly summarized as follows:

Class Lichenes:

1. Subclass Goniocarpi (ascocarp a mazaedium).

2. Subclass Discocarpi (ascocarp an apothecium):

(a) Series Grammophori (apotheoia lirelliform);

(b) Series Lecideales (apothecia lecideine);

(c) Series Parmeliales (apothecia lecanorine);

(d) Series Cyanophili (lichens with blue-green algae, including the Peltigeraceae and Stictaceae).

3. Subclass Pyrenocarpi (ascocarp a perithecium).

Special mention is made of the Work of A. Zahlbruckner (1907), who is responsible for the systematic account of the lichens in Engler and Prantl's Naturlichen Pflan-zenfamilien. He included lichens under a class Lichenes and divided into two subclasses on the basis of fungal component.

Subclass I. Ascolichens—fungal component Ascomycetes.

Subclass II. Hymenolichens—fungal component Basidiomycetes.

Ascolichens were subdivided into two series:
Series 1. Pyrenocarpeae, with perithecial fruiting body.

Series 2. Gymnocarpeae, with apothecial fruiting body.

These are further subdivided into orders and families.

The development of lichen thallus is the result of two organisms mutually affecting each other, but as the fungus provides the reproductive system, it is the dominant partner. The main lines of classification should be primarily determined by the nature of fungal component and its fruiting structure.

The algal component occupies a subsidiary position, but it is also of importance in shaping the form and structure of the lichen thallus. On the basis of above considerations Zahlbruckner's system of classification is widely acceptable and is generally followed by present-day lichenologists with minor modifications.

In the light of Zahlbruckner's system of classification, lichens are subdivided into two subclasses:
1. Ascolichenes, thallus with fungal component an ascomycete.

(i) Gymnocarpeae, ascocarp is an apothecium (Discolichens).

(ii) Pyrenocarpeae, ascocarp is a perithecium (Pyrenolichens).

2. Basidiolichenes, thallus with fungal component a basidiomycete.

Present Trend of Lichen Classification:
Since the lichen thalli and fruiting bodies are predominantly fungal in structure, it is only logical to classify lichens on the nature of various structures of the fungal component of the lichen thalli. There is no point to give taxonomic importance to the algal component of the lichen thallus.

The old lichen-oriented systems of classification do not work well to key the lichens down to orders, families, genera, and species. Naturally a rational integration of lichens with fungi for a workable classification system, is highly desirable. But the complexity of both the groups makes it very difficult.

Nannfeldt (1932) for the first time initiated the classification of lichens with fungi. Bessey (1950) in his Morphology and Taxonomy of Fungi included Ascolichens under the Ascomycetes. Comparatively new and revised systems proposed by Korf (1958) and Tomaselli (1962) have received little support from mycologists or lichenologists.

Though it is very difficult to present a suitable classification system of lichens which will be acceptable to both mycologists and lichenologists, yet, it will not be unreasonable to adopt a relatively conservative system outlined by Dennis (1960) for the British Ascomycetes which is again based on Nannfeldt's original classification of the Ascomycetes and subsequently modified by Luttrell (1955).

A simplified key is presented below:

A. Fruiting bodies of the thallus containing asci

Class Ascomycetes

B. Asci unitunicate, regularly arranged in a hymenium

Subclass Euascomycetes

C. Fruiting bodies apothecia Order Lecanorales

CC. Fruiting bodies perithecia Order Sphaeriales

CCC. Fruiting bodies mazaedia Order Caliciales

BB. Asci bitunicate, regularly or irregularly arranged in an ascostroma (pseudothecium) with-branched pseudoparaphyses.

Subclass Loculoascomycetes

C. Pseudothecia poorly differentiated, asci irregularly distributed

Order Myrangiales

CC. Pseudothecia well-delimited, resembling perithecia, asci more or less regularly arranged in the stromatic layer

Order Pleosporales

CCC. Pseudothecia well-delimited, round and resembling apothecia

Order Hysteriales

AA. Fruiting bodies containing basidia

Glass Basidiomycetes

AAA. Fruiting bodies unknown; thallus crustose to squamulose, poorly differentiated

Glass Fungi Imperfecti

Some of the Indian Lichens:
I. Crustose lichens:
1. Graphis duplicata Ach.

2. G. scripta Ach.

3. Haematomma puniceum (Sw.) Mass.

4. Lecanora chlarona (Ach.) Nyl.

5. L. distans (Pers.) Nyl.

II. Foliose lichens:
1. Gyrophora cylindrica (Linn.) Ach.

2. Peltigera scutata (Dicks.) Duby.

3. P. rufescens (Weis.) Humb.

4. Physcia aegiliata (Ach.) Nyl.

5. P. aspera H. Magn. and Zahlbr.

6. Parmelia cirrhata Fr.

7. P. furfuracea (Linn.) Ach.

III. Fruticose lichens:

1. Cladonia aggregata (Sw.) Ach.

2. C. pityrea (Flk.) Fr.

3. Usnea aspera (Eschw.) Wain.

4. U. dichotoma Fr.

5. Ramalina calicaris Rohl.

6. R. himalayensis Ras.

Note # 8. Specialized Structures of Lichen Thallus:

i. Aeration Structures of Lichens:

Though lichens are composed of two actively growing organisms, the lichen thallus increases very slowly. The absorption of water and mineral salts and corresponding formation of carbohydrates by the deep-seated chlorophyll cells of algae are in small amount. Hence active aeration is not very essential for the lichen thallus. There are many indirect channels by which air can penetrate to the deeper tissues.

In spite of this, gaseous exchange in the lichen thallus may take place through structures specially developed for the purpose which are as follows:

(a) Breathing pores:

These are localized openings developed in the upper cortex where the hyphae are loosely interwoven. There may or may not be cone-like elevation on the surface of the thallus accompanied with the breathing pores.

(b) Cyphellae (sing, cyphella):

These are also organs through which aeration in the lichen thallus takes place. They are concave circular depressions confined to the lower cortex of a few foliose lichens (Fig. 318B). The hyphae which grow out from the medulla line the cup and from the terminal cells of which short roundish cells with comparatively thin walls are abstracted in a spore-like manner.

These roundish cells give characteristic white powdery appearance to the cup.

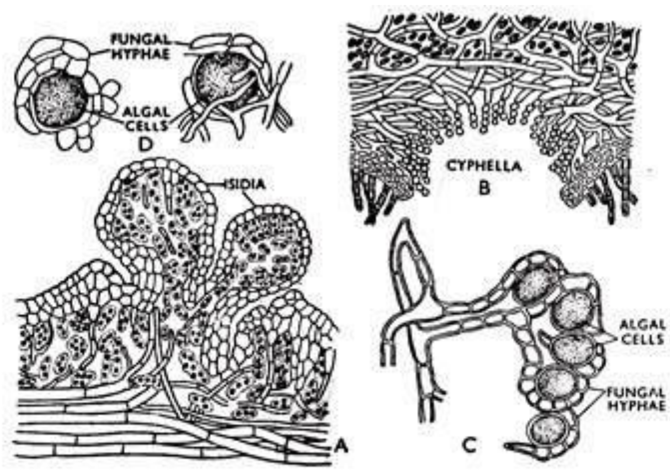

Fig. 318. Specialized structures of lichen thallus. A. Isidia of *Peltigera* sp. B. Cyphella of *Sticta* sp. C. Portion of algal layer showing association between fungal hyphae and algal cells. D. Soredia of *Physcia pulverulenta* and *Ramalina farinacea*.

(c) Pseudocyphellae:

These resemble cyphellae in every respect except in the fact that in them no margin is formed, the cortex is simply burst by the protruding filaments.

ii. Cephalodia:

These are external or internal gall-like swellings of the lichen thallus. They are dark-coloured consisting of the same fungal hyphae as in the lichen thallus but the algal component is always different. The cephalodia do not have any organic connection with the lichen thalli bearing them.

iii. Isidia:

These are coral-like outgrowths that are developed on the surface of the lichen thallus (Fig. 318A). They are composed of external cortical layer of fungal hyphae with an internal algal layer. They are distinguishable from the cephalodia by the fact that here the algal component is the same as that in the thallus, whereas, the cephaloidal alga is different from that of the thallus.

They are primarily meant for increasing the photosynthetic surface of the lichen thallus. At times they on being detached from the lichen thallus behave as reproductive bodies.

iv. Soredia:

The soredia are minute, rounded separable outgrowths of the lichen thallus. They are composed of algal cells clasped and surrounded by fungal hyphae (Fig. 318D). Both the fungus and the algal components are the same as in the parent thallus. Soredia are formed in fairly large number on the surface or margins of the lichen thallus.

They may occur in patches or may arise so abundantly as to spread up like a thin greyish layer of dust on the surface of the lichen thallus. The soredia are widely disseminated by wind or rain and on being deposited on a suitable substrate germinate giving rise to new thalli with all the characteristics of the parent.

v. Soralia:

In foliose and fruticose, and in a few crustose forms of lichens, the soredia are massed together into compact bodies known as soralia.

vi. Cilia:

Cilia are hair-like thalline appendages, decolourized or carbonized strands of hyphae that originate along the lobed margins or on apothecia.

Note # 9. Development of the Lichen Thallus:

Lichen-fungal spore on coming in contact with suitable substratum and under favourable conditions rapidly puts out germ tube; it may in some cases form numerous branches, which always perish after a certain time if they do not encounter suitable algae, even when the germination has taken place on a substratum favourable to the nutrition of the lichen thallus.

In cases where a certain number of algal cells adhere with the fungal spores that are ejected from the lichen thallus, they are ready at once to be seized upon by the germ tubes.

The germ tube puts out branches as soon as it comes in contact with the right alga. The branches embrace the alga and inclose it in fresh ramifications. At the same time the germ tube puts out other branches which penetrate into the nutrient substratum and evidently obtain the necessary mineral matter from it. If there is no substratum of this kind, the above processes do not go beyond the very first stage.

The union of the two components (alga and fungus) stimulates both, but more especially the fungus, to new developments of vegetative form, in which the fungus, as the predominant partner, provides the framework of the lichen thallus. Varied structures evolve in order to secure life conditions favourable to both constituents.

As the close association of the assimilating and growing tissues is maintained, the thallus thus formed is capable of indefinite increase.

The morphological characters of the alga when it is associated by the fungus experience a more or less profound change from its condition in the free state. Size, structure and arrangement of cells are affected in a manner which varies in the same species of alga according to the species of fungus to which it is associated.

The alga departing from its usual behaviour takes part in the development of the lichen thallus. The algal component multiples by division or by sporulation within the thallus. It absorbs water and nutriments from the fungal hyphae and assimilates carbohydrate food.

The nature of alga and the extent of algal layer are extremely variable in different lichen thalh. The ground tissue of the lichen thallus, apart from the algal layer is composed of hyphal elements.

The fungal component is dependent on the alga for the supply of carbohydrate food. It also takes advantage of the presence of humus, whether in the substratum or in the aerial dust. Since the rate of growth of a lichen thallus is very slow, there is not any large demand for nourishment.

Pseudolichens:

These are forms which have great resemblance with the true lichens. Most of them live on bark of trees. But they do not have the mode of life of true lichens. Their thalli do not possess algae. The fungi out of which their thalli are composed are of uncertain position since they form clustered spore-groups.

Some of the Pseudolichens are saprophytes, whereas, others are adapted to parasitic mode of life. These forms deserve further investigation.

Fossil Lichens:

Among fossil plants there are very few records of lichens due to their indistinct preservation a large number of them are of doubtful determination.

The earliest record of lichens from mesozoic are Ramalinites lacerus and Opegrapha, of which the former has been questioned. Ramalina tertiaria, Lichen dichotomus, Opegrapha thomasiana, Cladonia rosea, Parmelia lacunosa and many others have been reported from coenozoic.

Note # 10. Components of Lichen Thallus:

The algal components of the lichen thalli belong to the blue-green algae and green algae. Twenty-seven different genera of algae, both blue-green and green have been reported so far from lichen thalli, Most of the algae are land forms, and, in a free condition they inhabit moist or shady situations, tree-trunks, walls, etc.

They multiply by division or by sparulation within the lichen thallus. Usually Nostoc, Gloeocapsa, and Rivularia are common blue-green algae involved in the development of lichen thalli; and Pleurococcus (Protococcus), Cystococcus, Trenlepohlia, and Cladophora are among the green algae found in this relationship (Fig. 314).

The fungal components of the lichen thalli belong to the Ascomycetes and Basidiomycetes. The ascomycetous fungi produce either apothecia or perithecia bearing asci with ascospores and paraphyses in mature lichen thalli. The development of ascocarps in a lichen thallus is accomplished exclusively by the fungal component, the alga does not take any direct part in the process.

Lichen fungi combine with the same species of alga, and the continuity of genera and species is usually maintained. There are some exceptions where certain lichen fungi are able to associate separately with different algae and adopt strikingly different morphology with the different components.

For example, the lichen Sticta Jilix contains the green alga Coccomyxa, but a lichen formed by the same fungus with the blue-green alga Nostoc is so different in appearance that it is assigned to a different genus, Dendriicocaulon.

The fungal hyphae are thin-walled and are closely applied to the algal cells. The algal cell wall may be penetrated by peg-like haustoria, The extent of haustorial penetration is not at all clear (Figs. 314; 318C, D).

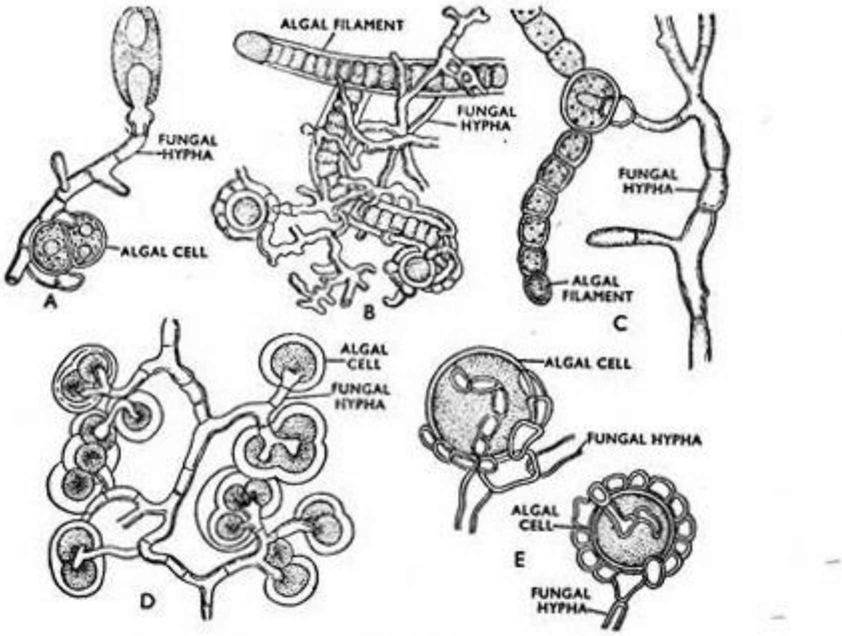

Fig. 314. Lichen-forming Algae. A. *Pleurococcus viridis*. B. *Scytonema* sp. C. *Nostoc* sp. D. *Gloeocapsa* sp. E. *Pleurococcus* sp.

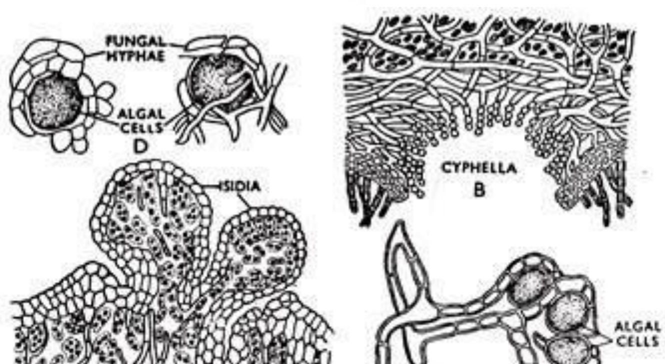

Fig. 318. Specialized structures of lichen thallus. A. Isidia of *Peltigera* sp. B. Cyphella of *Sticta* sp. C. Portion of algal layer showing association between fungal hyphae and algal cells. D. Soredia of *Physcia pulverulenta* and *Ramalina farinacea*.

Note # 11. Nature of Lichen Thallus:

i. External Features:

Lichens are of many different forms and colours. They range in size from minute types to large and conspicuous forms, and some attaining a length of several feet. Lichens vary greatly in colour; some are greyish-green, others are white, orange, yellow, yellowish-green, brown, or black. They commonly form thin thalli.

It is convenient and customary to divide lichens into three groups according to the external appearance of the thallus, although there is no sharp distinction between these groups, and this classification bears no relations to the taxonomic position of the fungi and algae involved.

Lichens which form a crust closely addressed to the substrate may be partly or wholly embedded in it are called crustose lichens (Fig. 315A); lichens with a more leaf-like thallus often resembling dried-up thallus of the liverwort with lobed or irregular margins, usually attached to the substrate by a relatively smaller portion are called foliose lichens (Fig. 315B); and lichens which are more or less bushy-branched to upright in habit are called fruticose lichens (Fig. 315D).

Special forms of fruticose lichens often designated as pendant forms possess long and slender branches which frequently remain hanging from the twigs or branches of trees being attached only at localized spots.

It should be noted that the distinctions of lichen thalli are not absolute for there are gradations between these groups. Most species of Cladonia are at first crustose to foliose but later form upright secondary branches called podetia upon which the apothecia are developed by that time the prostrate foliar growth disappears (Fig. 315G).

A crustose lichen thallus may also develop into a discrete lobed structure partially or wholly free of the substrate producing scaly appearance and is designated as a squamulose thallus.

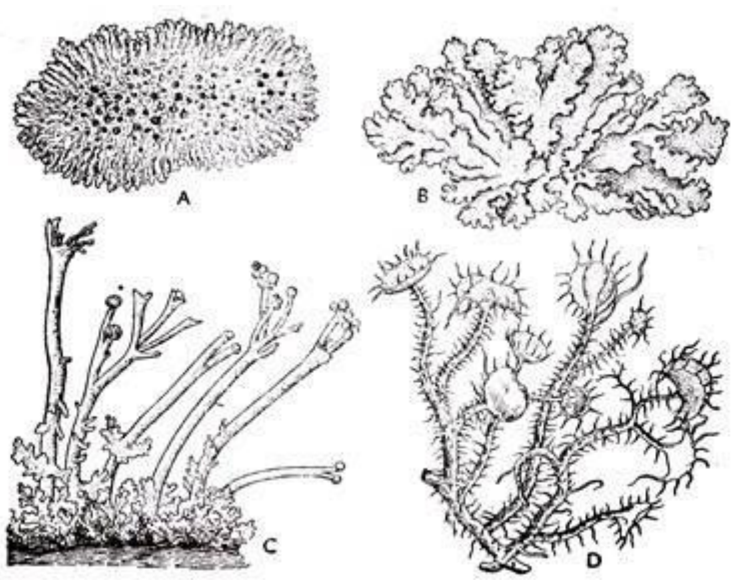

Fig. 315. Different forms of lichens. A. Crustose in *Graphis* sp. B. Foliose in *Parmelia* sp. C. Fruticose with a much-branched ribbon-like thallus bearing erect or pendant fruiting portion in *Cladonia* sp. D. Fruticose in *Usnea* sp.

ii. Internal Structure of Lichens:

The bulk of the plant body is composed of closely interwoven hyphae of the fungus in association with the algal component. The specialized hyphae, the rhizoids, extend downward and serve to attach the thallus to the substratum. The thallus is sponge-like and absorbs water. Mineral salts are obtained in part through the rhizoids also known as rhizines, in part from rain water and windblown dust particles.

(a) Foliose lichen:

A cross-section of a foliose lichen thallus shows internal differentiation of four zones. The uppermost zone consists of more or less vertical hyphae that are with (Fig. 316A) or without (Fig. 316B) intercellular spaces, which when present, are filled with gelatinous material. This is known as upper cortex which may or may not have an epidermis-like layer of hyphae.

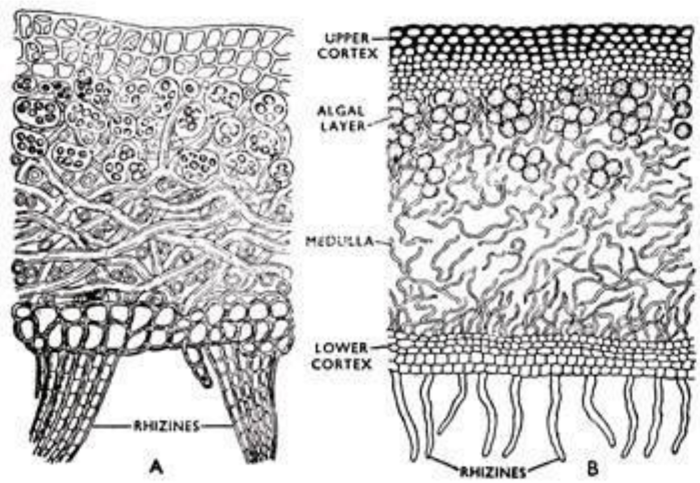

Fig. 316. Structural details of lichen thalli in section. A. Upper cortex with intercellular spaces. B. Upper cortex without intercellular spaces.

Beneath the upper cortex is the algal layer also known as gonidial layer (Fig. 316B). The algal layer consists of rather loosely interwoven hyphae intermingled with algae. The distribution of algal cells and the nature of algal layer in the lichen thalh may be variable. Thalli having the algal cells scattered uniformly among the enveloping fungal hyphae are known as homoiomerous.

Whereas, in others the algal cells are restricted to a single layer, they are called heteromerous. The heteromerous thalh are rather common than the homoiomerous ones. The layer beneath the algal layer is composed of very loosely interwoven hyphae and is designated as a medulla.

Beneath the medulla is the lower cortex consisting of compact hyphae (Fig. 316B).

The thallus is attached to the substratum by certain hyphal structures known as rhizines which arise from the underside of the lower cortex (Fig. 316A & B). Rhizines may be simple or branched. In some genera (Anzia. and Pannoparmelia) an unusual development of hyphae from the lower cortex occurs which on anastomosing form a loose sponge-like layer known as hypothallus (Fig. 317).

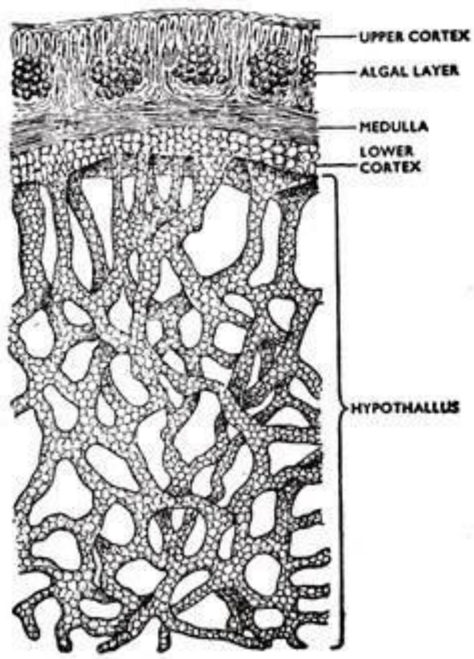

Fig. 317. *Pannoparmelia anzioides*. Vertical section of thallus and hypothallus.

(b) Crustose lichen:

The crustose lichens, which have very poorly defined thallus, in general, have a similar structure but the development of the different layers is not so complete like that of foliose lichen. The tissues forming the thallus are arranged more or less in strata one above the other.

The upper cortex is of hyphal layer, either rudimentary or highly elaborated, beneath which is the algal layer composed of algae and fungal hyphae in close association. Deeper down the algal layer is the medulla, generally a loose tissue of branching hyphae.

The lower cortex which lies next to medulla may be as fully developed as the upper or it may be absent. The hyphae on the edge remain meristematic and provide for horizontal as well as vertical extension of the thallus, along with which there is also continual increase of the algal cells.

(c) Fruticose lichen:

The fruticose lichens which are usually much branched, are either busy and erect or pendant. Their thalh exhibit no differentiation into an upper and lower surface, but are attached to the substrate by a definite basal portion composed of strands of densely-packed hyphae.

The conditions of strain and tension in the upright thallus are entirely different from those in the decumbent thallus, and to meet the new requirements, new adaptations of structure are provided either in the cortex or in the medulla. The cortex consisting of parallel hyphae with thickened walls forms the strengthening element.

It is further strengthened by the compact arrangement of the medullary hyphae which run parallel with the surface.

Note # 12. Relationship between Components of Lichen Thallus:

A lichen is an intimate association of a fungus and an alga in which both the organisms intertwine to form a single thallus. The fungal component is called the mycobiont, and the algal component is known as the phycobiont.

Many species of Ascomycetes and few species of Basidiomycetes are found growing in close association with one of several genera of green or blue-green algae constitute lichen thalli. The fungus always envelopes the algal component of the association and the resulting thallus from the combined growth of the two are more less constant in form and in internal structure.

Every individual of a given lichen species contains the same alga and the same fungus.

The relationship between alga and fungus in a lichen is a matter of controversy. Some are of opinion that the fungus lives during all or a part of its life in parasitic relation with the algal host and also sustains a relation with an organic or an inorganic substratum (Fink, 1913 and others).

Others regard the relationship between an alga and a fungus in a lichen thallus as purely of parasitism, the fungus being parasitic on the alga, as evidenced in some cases by the presence of fungus haustoria in the algal cells (Geitler, 1937). The fungus not only parasitizes the algal cells but also lives saprobically on the dead algal cells.

But in healthy lichens, dead or digested algal cells are observed only rarely and the true extent of haustorial penetration is not at all clear.

Again it has been demonstrated experimentally that the alga of lichen thallus can be grown without the fungus, whereas the lichen associated fungus cannot survive without the alga which indicates the dependence of the fungus on the alga.

Experimental evidences also indicate that the alga in a lichen thallus maintains a high level of soluble carbohydrates in the fungal hyphae—this being a major factor in the ability of lichens to with and environmental extremes.

The movement of photosynthate of the alga to the fungal hyphae is predominantly as a simple carbohydrate—glucose from blue-green algae such as Nostoc and from green algae either erythritol as in Trentepohlia, ribitol as in Trebouxia, or sorbitol as in Hyalococcus.

But the flow of carbohydrate out of the algal cells ceases rapidly after isolation from the thallus resulting in a substantial increase in polysaccharide formation within them. All the blue-green algae of lichen thalli so far investigated are very active in nitrogen fixation.

Over 90 per cent of the fixed nitrogen passes rapidly to the fungal hyphae probably as ammonia. Apparently during the association of a fungus and an alga in a lichen thallus the fungus stimulates the flow of simple carbohydrate and ammonia from algal cells to the fungal hyphae.

But the basic cause of this phenomenon is yet to be established. Although the algae only occupy a small volume of the lichen thalli they are able to work a remarkable morphogenetic response from the associated fungi.

It-is evident that in the evolutionally sense lichens originated through helotism (master and slave), a partnership between an alga and a fungus in which the association is decidedly at the expense of the alga. Thus, it appears that the benefits of the association are heavily in favour of the fungi.

For this reason, and because the form and structure of the lichen thallus are usually governed largely by the fungus rather than the alga, the International Code of Botanical Nomenclature provides that the name of a lichen is that of its fungal component.

Lichens have long been taken as a standard example of true symbiosis, in which both symbionts benefit from the association (Scott, 1960). The lichen thallus was considered to represent an idyllic marriage, a consortium between the fungus and alga. It is clear that the fungus benefits, since it is wholly dependent on the alga for food, but it is not always equally clear that the alga benefits.

Some lichens grow in dry places where algae alone could not survive, but some others occur side by side with the algal component. The algal cells may receive some benefit from the fungus by way of absorption and retention of water. Experimental work suggests that some lichen fungi produce substances which stimulate or are necessary to the growth of the included algae.

The alga survives because of its association with the fungal pseudoparenchyma formed in such a way as to give protection to the algal cells against unfavourable conditions. A very delicate balance thus exists in the relationship which if disturbed in favour of either may result in the destruction of the less favoured component.

The concept of polysymbiosis has been put forward by some workers who detected a combination of an alga, a fungus and nitrogen fixing bacteria Azotobacter in a lichen thallus where all the three partners act in union as polysymbionts.

But in the same lichen thallus exists the phycobiont Nostoc which fixes appreciable amount of nitrogen and there is no evidence whether nitrogen fixation be attributable to Azotobacter or Nostoc.

Of late, a number of lichen fungi were grown in pure culture away from algal component. Attempts to synthesize lichens artificially in the laboratory have produced some positive results, but more to be done before drawing any conclusion.

Note # 13. Reproduction of Lichens:

Lichens reproduce both by asexual and sexual methods. Many lichens reproduce by simple process of progressive growth and decay of the thallus. Older portions die off leaving the tips to continue growth as separate individuals.

i. Asexual Method:

The asexual method of reproduction is rather common. Under this category the vegetative method of reproductions is also included.

(i) Fragmentation:
The fragmentation of the lichen thallus may be accomplished by (a) death and decay of the older portions, and (b) accidental breaking. The broken-off pieces develop into new thalli provided they contain both the components.

(ii) Development of special reproductive structures:
The most common ones are, soredia. Like soredia, isidia also may give rise to new lichen thalh.

(iii) Asexual spore formation:
Many lichens produce conidia in pycnidia immersed in the thallus. The conidia on being dispersed germinate under favourable conditions by sending out hyphal branches in all directions. Any of the hyphal branches on coming in contact with the appropriate algal cell, branches further ultimately producing a lichen thallus.

ii. Sexual Method:
With a few exception of tropical lichens whose fungal components are of Basidiomycetes, all known lichens possess fungal elements belonging to the Ascomycetes and these lichens reproduce by ascospores developed in asci. Synthesis of lichen thallus occurs through union of germinating fungal spore and algal cells.

Note # 14. Types of Lichen:
Lichens are of two kinds: Ascolichen and Basidiolichen. Ascolichens possess fungal elements belonging to the Ascomycetes and those of Basidiolichens are of the Basidiomycetes.

Ascolichen:
Ascolichens (Fig. 319) may be grouped into: ascohymenial lichens and ascolocular lichens. Ascohymenial lichens are those in which asci. are borne in apothecia or perithecia. Whereas in the ascolocular lichens asci are scattered in the locules of the stroma and a true hymenium is lacking.

(i) Ascohymenial lichens:

In these lichens there is formation apothecia (Fig. 319A) and perithercia which may be embedded in the thallus, stand somewhat above it or be subtended by long stalks. The production of ascocarps in a lichen thallus is accompanished exclusively by the fungal component, the alga taking no direct part in the process.

The development of ascocarp is initiated by the differentiation of an ascogonium from the rest of hyphae. The ascogonium is many-celled with the upper end differentiated into a trichogyne. The tip of the trichogyne projects beyond the thallus and receives spermatia produced in spermogonia developed near the ascogonium.

The asci and ascospores are produced by the formation of ascogenous hyphae and croziers. The ascocarp is lined with a palisade-like sterile hyphae growing vertically are the paraphyses.

The asci grow mixed with .the-paraphyses (Fig. 319B). The development of asci and paraphyses may continue for several years. The asci usually bear eight ascospores which may be one-celled or two- (Fig. 319C) to many-celled.

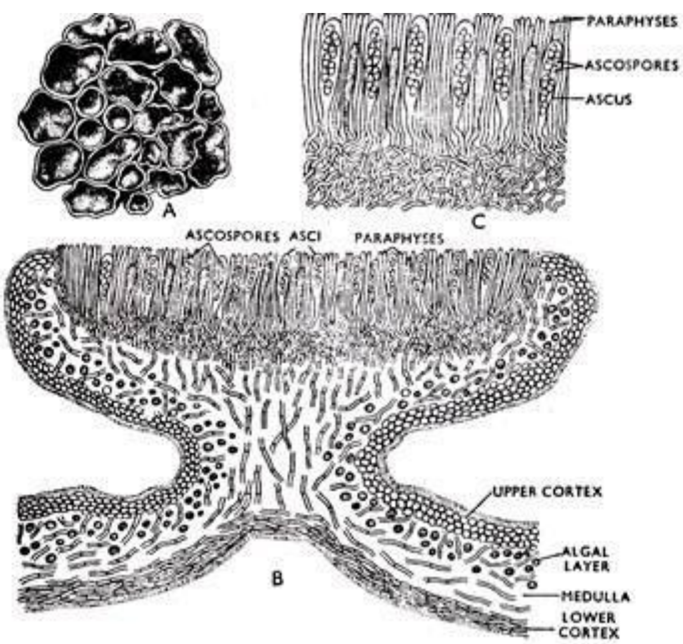

Fig. 319. Structural features of Ascolichen thallus and apothecium. A. Apothecia of Ascolichen thallus. B. Sectional view of apothecium and Ascolichen thallus. C. Portion of hymenium of apothecium showing asci bearing ascospores and paraphyses mixed with asci.

(a) Apothecia:

The apothecia generally share the characters of the parent thallus in colour and consistency.

They may be: immarginate, without a well-marked margin; marginate, having a well-marked edge; lecanorine, possessing a thalline margin; biatorine, apothecia being soft or wax-like, and frequently brightly coloured; lecideine, apothecia dark-coloured or carbonaceous and generally having no thalline margin; or lirelliform, a long, narrow apothecium.
Apothecia are typically open disc- or cup-shaped structures. The hymenium is a thin layer of asci and paraphyses lining the inner surface of the cup. Spores are ejected from the asci forcibly by pressure of swollen moistened ascus walls.

There is a small group of lichens in which asci disintegrate at maturity and spores are liberated free in a mucilaginous or dough-like layer over the hymenial surface, made up of tips of the paraphyses and their secretions. This is so-called mazaedium.

(b) Perithecia:
The perithecia wherever formed are also identical with those of the Ascomycetes. A perithecium is described as entire when it is partially or entirely immersed in the lichen thallus or in the substratum on which the lichen grows, and is either globose or conical in shape and wholly surrounded by a hyphal wall.

Whereas, it is designated as dimidiate when the perithecium is somewhat hemispherical in form and the outer wall is developed only on the upper exposed part of the lichen thallus. As the peiithecial wall gives sufficient protection to the asci, the paraphyses are of less importance and are frequently very sparingly produced.

(ii) Ascolocular lichens:
The ascolocular lichens differ from ascohymenial lichens, as indicated above, in lacking a true hymenium and in having bitunicate asci interspersed with pseudoparaphyses, remaining scattered in locules of stroma. Organized, though often weakly delimited, such fruiting bodies are designated as pseudo- thecia or ascostromata.

Basidiolichen:

Fungal elements of Basidiolichens (Fig. 320) are mostly related to the Thelephoraceae, along with which blue-green algae are associated. Their thalli stand out from the trees like small thin bracket fungi (Fig. 320A). There is no cortex in the thallus, except in cases where a rather compact cover is formed on the upper surface by hyphal anastomosis.

The algal layer which lies at the base of the upward branches is surrounded with thin-walled short-celled hyphae closely interwoven into a kind of cellular tissue (Fig. 320B). The medulla of loose hyphae passes over to the lower cortex producing an uneven lower surface. A lichen thallus when spread over soil produces hypothallus without rhizines.

Again thalli growing on trees develop extensive hold-fast tissue. The spores are exogenous and are borne at the tips of basidia which are produced on the undersurface of the thallus.

In some cases the fertile filaments may form a continuous series of basidia over the surface of the thallus, but generally they grow out in separate, though crowded, tufts. With the broadening of these tufts a continuous hymenial layer is formed. Each basidium bears four sterigmata and basidiospores (Fig. 320G & D); paraphyses exactly similar to the basidia are abundant in the hymenium.

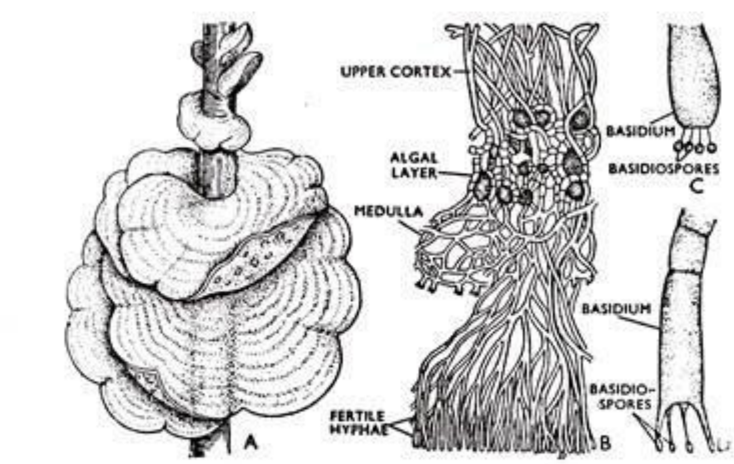

Fig. 320. Morphology and structure of Basidiolichen *Cora pavonia*. A. Thin bracket-like thalli. B. Vertical section of thallus. C–D. Basidia with basidiospores.

Note # 15. Harmful Effects of Lichens:

Large number of lichens have been found causing harmful effects in various way:

1. Lichens of the genera Cladonia and Amphiloma cause total destruction to the colonies of mosses by direct parasitic attack. The hold-fast hyphae of Usnea often pierce through the cortex to the inner tissue of the host, destroy the middle lamella of the cell wall, and ultimately enter in the cells causing total destruction.

2. Lichens often cause serious damage to-the window glasses in old buildings. They attach themselves to the glass and gradually corrode it with the help of excretion of acids.

Note # 16. Diseases of Lichens:

Lichens are subject to various diseases. Following are some of the causes of diseases of lichens:

i. Caused by Parasitism:

Diseases of lichens due to parasitism by fungi or by other lichens are very frequent. But only in rare cases there is total destruction or any permanent harm to the host resulted by such parasitism. The thallus of Parmelia encausta is dwarfed and deformed by the parasitic attack of Physcia villosa.

ii. Caused by Crowding:

Lichens very often suffer from being overgrown by other lichens. They may also be crowded out by other plants.

iii. Caused by Adverse Conditions:

Certain adverse conditions frequently induce disease symptoms. There may be cracking of the lichen thallus due to certain adverse conditions prevailing in and around the substratum of the lichen thallus.

Besides this, the adverse conditions also induce the undue thickening of the cortex in the thallus of Pertusaria communis whereby the formation of the fruiting bodies is inhibited and even development of the thallus is hampered. Unusual swellings are produced in the thallus of Usnea articulata due to abnormal air currents.

Note # 17. Economic Importance of Lichens:

Lichens are useful to nature and human life:

i. Pioneer Initiators of Rock Vegetation:

Lichens are of considerable ecological importance as pioneers in colonization of rocky habitat by plants They excrete organic acids which disintegrate rocks, thus forming soil and preparing substrata in which other kinds of plants can subsequently become established.

Thus, the growth of lichens on bare rocks initiates the weathering away of such rocks. The kind of lichen to appear first depends on the flora existing in the neighbourhood. Crustaceous species are most subject to this struggle for existence and are the first to lay foundation of vegetation. First lichen to appear on rocks, for instance, is Lichen candelarius. Other species of Lichen follow soon after.

ii. Soil-Formers:

Lichens perform the work of breaking down the hard rock surfaces and preparing a soil on which more highly developed plants can grow. Usually crustaceous lichens begin to cover the area. When they die, their decaying remains, together with rock particles, form a soil in which other plants may grow. The first successors are generally mosses, but sooner or later vascular plants begin to grow in the soil.

A succession of Lecanora saxicola, then the moss Grimmia pulvinata, which forms compact cushions on which later grow Poa compressa, small crucifers, etc., may be cited as an example.

iii. Food for Insects and Similar Other Organisms:

Some species of lichens, such as, Aspicilia calcarea and Lecanora saxicola are included in the diets of mites, caterpillars, termites, and snails.

iv. Food for the Higher Animals:

Many lichens, if deprived of the bitter principle they contain, by soaking in water, or with the addition of sodium or potassium carbonate, might be used with advantage as fodder for animals. Such lichens are, Lobaria pulmonaria, Evernia prunastri, Ramalina fraxinea and Ramalina fastigiata, all of which owe their nutritive quality to the presence of lichenin, a carbohydrate allied to starch. Cladonia rangiferina, the Well-known ‘reindeer moss’, is the lichen most favourite as food for reindeer, cattle, etc. Alectoria jubata, Stereocaulon paschale, and Cetraria islandica are good for horses, oxen, cows and swine.

v. Food for Human Being:

Lichens contain lichenin, a carbohydrate very much allied to starch. But no true starch nor cellulose is present in the lichen thallus. Cetraria islandica, the commercial ‘Iceland Moss’ is supplied from Sweden, Norway or Iceland is used as food by man. After removing the bitter principle by soaking in a weak solution of sodium or potassium carbonate it is dried and reduced to powder.

The powder when boiled in water yields a jelly which forms the basis of various soups or other dishes prepared by boiling in milk, which are useful to dyspeptics or sufferers from chest diseases. The Egyptians have used Evernia prunastri in baking when yeast as fermentative agent was not known to them. In India, a species of Parmelia has been used as food, generally prepared as a curry by the natives.

It has also been utilized as a source of medicine. In Japan, Endocarpon miniatum which they name in English as ‘stone mushroom’ is sold in the market like vegetables.

vi. Source of Medicine:

Lichens owe their repute as curative herb to the presence of in the thallus lichenin and of some bitter or astringent substances, which, in various ailments, proved of real service to the patient, though they have now been discarded in favour of more effective drugs. Various medicinal benefits of lichens have been ascribed since Pre-Christian times.

Lichens have been used in the treatment of jaundice, diarrhoea, fevers, epilepsy, hydrophobia, and skin diseases. In Iceland, lichen is used as a laxative. Lichen is also used as an ingredient in culture media for bacteria. A preparation of Peltigera canina has been used to cure hydrophobia. Parmelia saxatilis, the ‘skull lichen’ has a medicinal property which can cure epilepsy.

Several species of Pertusaria and of Cladonia as well as Cetraria islandica were recommended in cases of intermittent fever; species of Usnea and Evernia furfuracea were used as astringents in haemorrhages; and Cladonia pyxidata was found specially valuable in whooping cough.

vii. Useful in Perfumery:
Lichens are used in perfumery in different ways. French perfumers extract an excellent perfume from Evernia prunastri. A still finer perfume is extracted from Lobaria pulmonaria. The virtue of the lichens also lay in their capacity to absorb and retain perfume. Different species of lichens are ground to powders to be used for cosmetic purposes.

The thalii of species of Usnea possess the power of retaining scent, and are profitably utilized in perfumery. Powdered thallus of Ramalina calicaris is often used as a substitute for starch that is used in perfumery.

A product obtained from European species of Evernia is widely used as a stabilizer in perfumes. In France, certain aromatic substances' are extracted from lichens and are used in soaps.

viii. Preparation of Dyes:
Some lichens produce dyes which have been used, since Pre-Christian times, for colouring fabrics and paints; among them are orchil, a beautiful blue dye, and cudbear, another blue dye.

The value of Roccella as a dye- yielding lichen has been recognised from the time of Theophrastus. The product extracted from its thallus was called Orseille for which the English name is orchil or archil and orcein is a purified product of orchil. Lichens serve as a source of the litmus commonly used in the chemical laboratory.

Litmus solution is made by grinding the lichen, Roccella tinctoria, and extracting the colouring matter, after which paper is soaked in the neutralized solution and is then known as litmus paper.

ix. Useful in Tanning, Brewing and Distilling:
In parts of Russia and Siberia, lichens are used in the brewing of beer. Some lichens contain tannins and are used for tanning animal hides in France and other European countries.

The astringent substances extracted from the thalli of Cetraria islandica and Lobaria pulmonaria have been made use of in tanning leather. Lobaria pulmonaria has also been used in the brewing of beer. Cladonia rangiferina, Usnea florida and Ramalina fraxinea have been used in the preparation of alcohol.