Lichens

21.1 WHAT IS A LICHEN?

Lichen is such an association of an alga and a fungus in which two organisms remain so closely associated with each other that they appear to be a single plant. The definition of the 'lichen' which was the winner in a poll amongst the members of the '*International Association for Lichenology*' held in 1981 is:

'A lichen is an association of a fungus and a photosynthetic symbiont, resulting in a stable thallus of specific structure'.

However, in 1983 edition of the *Dictionary of the Fungi* a lichen has been defined as 'a stable self-supporting association of a mycobiont and a photobiont'. The *mycobiont* is the fungal partner, whereas the *photobiont* is the photosynthetic partner in a lichen association.

According to the majority of the lichenologists a *symbiotic relationship* exists between the two partners of the association. The fungus parasitizes the algal cells, as well as also lives saprobically on the algal cells, which die because of either parasitism or other causes. On the contrary algal cells are protected from high light intensity. Water and some nutrients are also being made available to the alga by the fungus.

21.2 COMPONENTS OF LICHENS

A lichen consists of two components, an alga (*photobiont*) and a fungus (*mycobiont*). *The mycobiont* is usually a member of Ascomycotina, less commonly of Basidiomycotina, and only rarely of Deuteromycotina. The *photobiont* is usually a member of Myxophyceae (blue-green algae), and less commonly of Chlorophyceae (green-algae). In most of the earlier literature, however, instead of 'photobiont' the word 'phycobiont' (Gr. *phykos*, alga; *bios*, life) is used, which indicates its algal nature. But the recent trend is to treat blue-green algae as Cyanobacteria and not as algae. Based on this trend Hawksworth and Hill (1984) divided the photobionts into 'phycobionts' (Green algae) and 'Cyanobionts'(Cyanobacteria).

A majority of the ascomycetous lichens belong to either Discomycetes or Pyrenomycetes. Some also belong to Loculoascomycetes. But none belong to Mastigomycotina, Zygomycotina, Hemiascomycetes, Plectomycetes and Laboulbeniomycetes.

Hawksworth and Hill (1984) mentioned that out of a total number of about 13,500 lichenized fungi, about 13,250 species (98%)belong to Ascomycotina. According to these workers 46% of all species in the Ascomycotina are lichen-forming species. All species belonging to Graphidales, Gyalectales, Peltigerales, Pertusariales and Teloschistales of Ascomycotina form lichens.

Some of the lichen-forming genera of Basidiomycotina are *Dictyonema*, *Omphalina* and *Multiclavula*.

Only 55 species of lichen-forming Deuteromycotina have so far been described (Hawksworth and Hill 1984), of which *Blarneya hibernica* is very common.

According to Hawksworth and Hill (1984) only 37 genera have so far been identified as lichen photobionts, mostly belonging to blue greens (Cyanophyta) or green algae (Chlorophyta). Common lichen-forming blue-green algae are *Anabaena, Calothrix, Chroococcus, Gloeocapsa, Nostoc, Scytonema* and *Stigonema*. Common Chlorophyta are *Cephaleuros, Chlorella, Phycopeltis, Trebouxia* and *Trentepohlia*.

21.3 A BRIEF HISTORY

Theophrastus was the first person who introduced the word 'Lichen' (*lie, ken*) into Greek literature in about 300 *BC*. He used the word primarily to describe the outgrowths from the bark of olive trees. P.A. Micheli (1729), an Italian botanist, described about 300 species of lichens in his *Nova Plantarum Genera*. Hawksworth and Hill (1984) mentioned the Erik Acharius (1757-1819), a Swedish doctor, must be credited as the founder of the systematic study of lichens. The works of the Acharius are discussed in *Methodus Lichenum, Lichenographia Universalis* and *Synopsis Methodica Lichenum*. Among the recent workers the name of V. Ahmadjian comes on top. The author feels that because of the Ahmadjian's detailed study on lichens (Ahmadjian, 1960,1962,1965,1967,1970,1980,1982; Ahmadjian and Hale,1973; Ahmadjian and Jacob, 1983, etc.), he should be named the '*Father of Modern Lichenology*'. Hale (1967), Richardson (1975), Alvin (1977) and Hawksworth and Hill (1984) have also written general accounts of lichens.

21.4 OCCURRENCE

Lichens are found growing in a wide variety of situations from the Arctic to Antarctic and all regions in between. Some lichens are able to live where there is no other vegetation, and thus prove important colonizers of bare rocks. They may grow on leaves, bark of trees, soil, bare rocks, and many other similar situations. On one hand lichens grow commonly on exposed rocks in the desert, as well as near volcanoes, whereas on the other some lichens grow luxuriantly on frozen substrata in polar regions (*Cladonia rangifera*). A number of species occur only on the seashore.

Peltigera canina (Fig. 21.1 *A*) and *Xanthora parietina* grow commonly on walls, rocks, soil, and also amongst grass in woods, on lawns and sand-dunes. *Parmelia physodes* (=*Hypogymnia physodes*) is common on twigs(Fig. 21.1*B*), branches, wood, rocks and walls forming large, well-branched masses. *Usnea subfloridana* (Fig. 21.1*C*) grows commonly on trees, specially in hilly regions, whereas *Cladonia coccifera* (Fig. 21.1*D*) and *C.floerkeana* (Fig. 21.1*E*) are common on moorland and in hilly regions. *Cora pavonia* (Fig. 21.1*F*), a basidiolichen, occurs on bare soil and on trees.

Based on their place of occurrence, lichens may fall in following groups:

1. *Corticolous* : Lichens developing on bark of trees, e.g. species of *Parmelia, Alectoria, Usnea, Graphis* , etc.
2. *Lignicolous* : Lichens developing directly on wood, e.g. *Calicicum, Chaenotheca, Cyphelium*, etc.
3. *Saxicolous* : Lichens developing on rocky substrata, e.g. *Verrucaria, Porina, Dermatocarpon, Xanthora*, etc.
4. *Terricolous*: Lichens growing on the ground, e.g. *Cladonia floerkeana, Lecidea granulosa, Collema tenax* , etc.

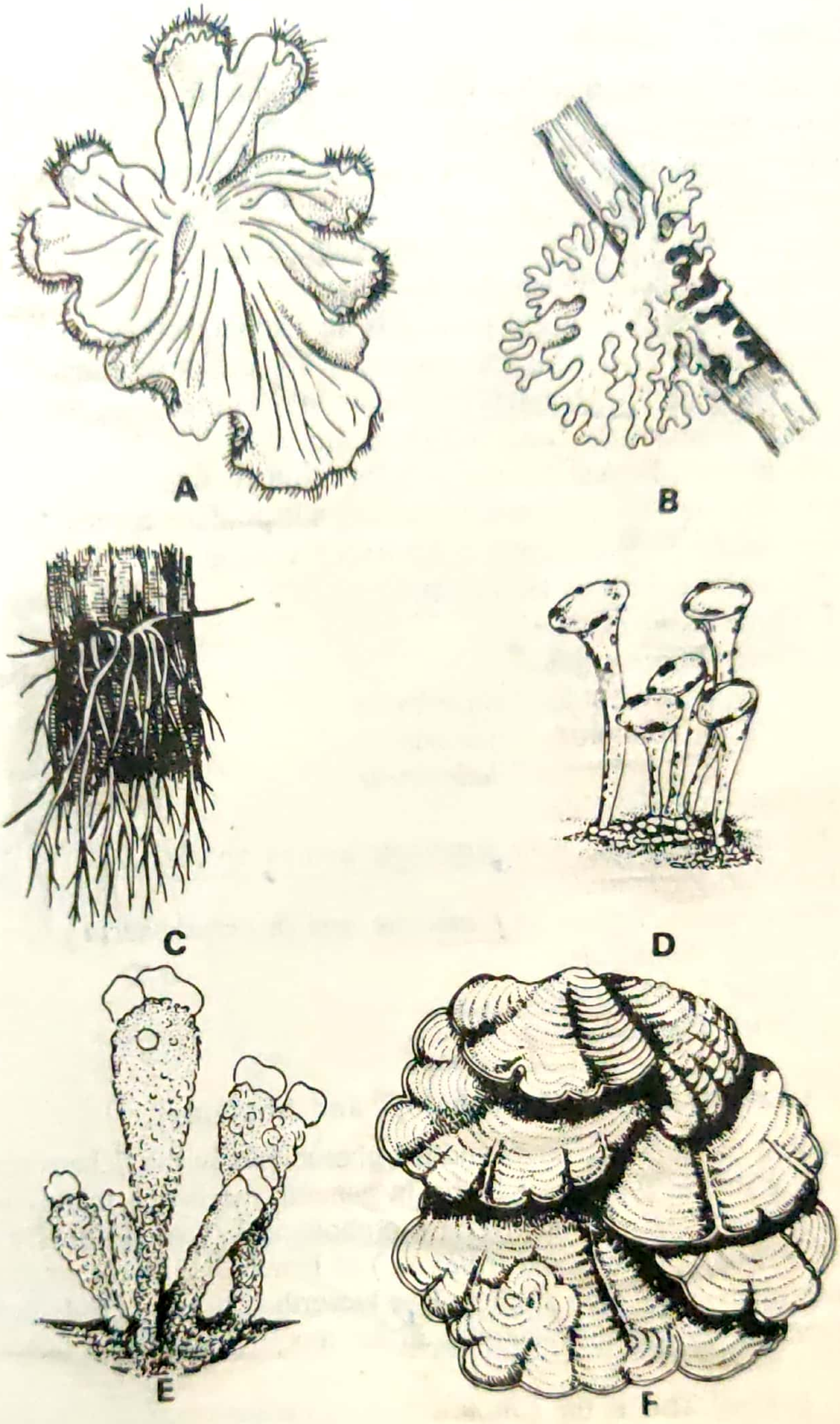

Fig.21.1 Thalli of some lichens. A, *Peltigera canina*; B, *Parmelia physodes*; C, *Usnea subfloridana*; D, *Cladonia coccifera*; E, *C. floerkeana*; F, *Cora pavonia*

5. *Marine* : Lichens developing on siliceous rocky shores of sea, e.g. *Verrucaria mucosa, Caloplacentum marinae, Caloplaca marina* etc.
6. *Freshwater* : Lichens developing on hard siliceous rocks in freshwater, e.g. *Hymenelia lacustris, Epheba lanata*, etc.

Many man-made substrata, such as leather, silk, wool, hairs, bone, glass fibre, timber, walls, paints, sculptures, asbestos-cement, worked-iron, glass etc., may also be colonized by lichens (Hawksworth and Hill, 1984).

Singh (1981) reported 145 microlichen taxa belonging to 43 genera, from Manipur (India).

21.5 CLASSIFICATION

Under the rules of the International Code of Botanical Nomenclature, no taxonomic significance is attached to the algal component. The lichen classification is based solely on the fungal partner. It is because the thalli and fruiting bodies of the lichens are largely fungal in structure.

According to Miller (1984) lichens are assigned subdivision status in true fungi (Eumycophyta), and are divided into two classes:

1. Class *Ascolichens* : Fungal partner is an Ascomycotina
2. Class *Basidiolichens* : Fungal partner is a Basidiomycotina

However, Poelt (1973), Henssen and Jahns (1974) and Alexopoulos and Mims (1979) divided lichens into three groups as under:

1. *Basidiolichens*: Fungal partner is a Basidiomycotina
2. *Deuterolichens* : Sterile lichens that do not produce spores
3. *Ascolichens* : Fungal partner is an Ascomycotina
   (a) *Hymenoascolichens with unitunicate asci*
      1. Order *Caliciales*
      2. Order *Lecanorales*
         i. Suborder *Peltigerineae*
         ii. Suborder *Lecanorineae*
         iii. Suborder *Cladonineae*
      3. Order *Graphidiales*
   (b) *Loculoascolichens with bitunicate asci in apothecia*
      1. Order *Arthoniales*
   (c) *Loculoascolichens with bitunicate asci in pseudothecia*
      1. Order *Dothideales*
      2. Order *Verrucariales*
      3. Order *Pyrenulales*

21.6 LICHEN THALLUS (Morphology and Anatomy)

The association of the mycobionts and the photobionts in the lichens results in the formation of a thallus-type plant body. In general, the lichen thallus is irregular, variously coloured, and shows several morphological types. Formerly only three basic types (*crustose, foliose* and *fruticose*) of lichen thalli were recognized. But, on the basis of their detailed studies, Hawksworth and Hill (1984) described the following categories and subcategories in the morphology of the lichen thallus:

1. *Leprose lichens:* This is the simplest type of thallus organization, in which the fungal hyphae envelope either single or small cluster of algal cells. A distinct fungal layer does not envelope the algal cells all over. The so-formed simple lichen thallus grows superficially over the substratum, provides a powdery appearance, and is called *leprose*, e.g. *Lepraria incana* (Fig. 21.2).

Fig. 21.2 A leprose lichen thallus of *Lepraria incana*

2. *Crustose lichens:* In these lichens (*Buellia, Strigula, Dimerella, Graphis*) the thallus is very closely adhered to the substratum, and provides a crust-like appearance (Fig. 21.3). It is very difficult to separate them from the substratum. The photobiont (algal) cells are covered by a distinct layer of fungal tissue (cortex).

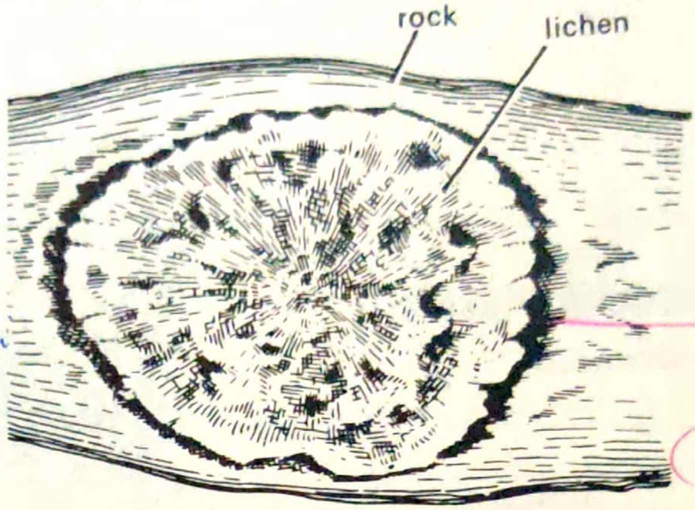

Fig. 21.3 *Caloplaca thallincola*, **a crustose lichen**

In crustose lichens the outer surface is smooth, and may be continuous or dissected by wandering cracks. In some genera, such as *Rhizocarpon*, the outer surface contains many polygonal structures, called *areolae*. When the areolae grow out to form coralloid tufted cushions, they are called *suffruticose*.

Some variations of the crustose types are mentioned below:

1. *Placodioid* : When the outer surface is radially striate and contains slightly raised marginal tissues, the lichen is called *placodioid* or *placoid*, e.g. *Lecanora* and *Caloplaca*.
2. *Squamulose* : When the outer surface contains overlapping scale-like squamules, the crustose-lichen is called *squamulose* ,e.g. *Psora*.

Internally a crustose lichen is usually differentiated into cortex, algal zone and medulla (Fig. 21.4*A*). The cortex and medulla are made up of fungal hyphae Some hyphae of the medulla may form pointed rhizoids, which enter into the substratum.

3. *Foliose lichens:* The thallus is flat, leaf-like, well-branched, lobed, and attached to the substratum with the help of rhizoid-like *rhizines*. The external appearance is like that of crinkled and twisted leaves, e.g. *Parmelia* (Fig. 21.1 *B*), *Physcia, Collema, Peltigera* (Fig. 21.1*A*) etc.

Internally, along with the presence of a separate *upper cortex* on the upper side followed by an *algal layer* and a thick *medulla*, foliose lichens also have a well-organized *lower cortex*. From some cells of this lower cortex develop *rhizines* or some other type of attachment organs. The regions of the upper cortex, medulla and lower cortex are formed by the fungal hyphae.

Foliose lichens may fall into any of the following categories (Hawksworth and Hill, 1984):

1. *Homoiomerous* : The algae in some lichens are distributed more or less evenly throughout the thallus, as in *Collema* (Fig. 21.4*B*). Such lichens are called *homoiomerous*.
2. *Heteromerous* : The algal cells in majority of the foliose lichens form a distinct layer (*algal zone*) within the thallus (Fig.21.4C). Such lichens are called *heteromerous* e.g. *Parmelia*, *Physcia*, etc.

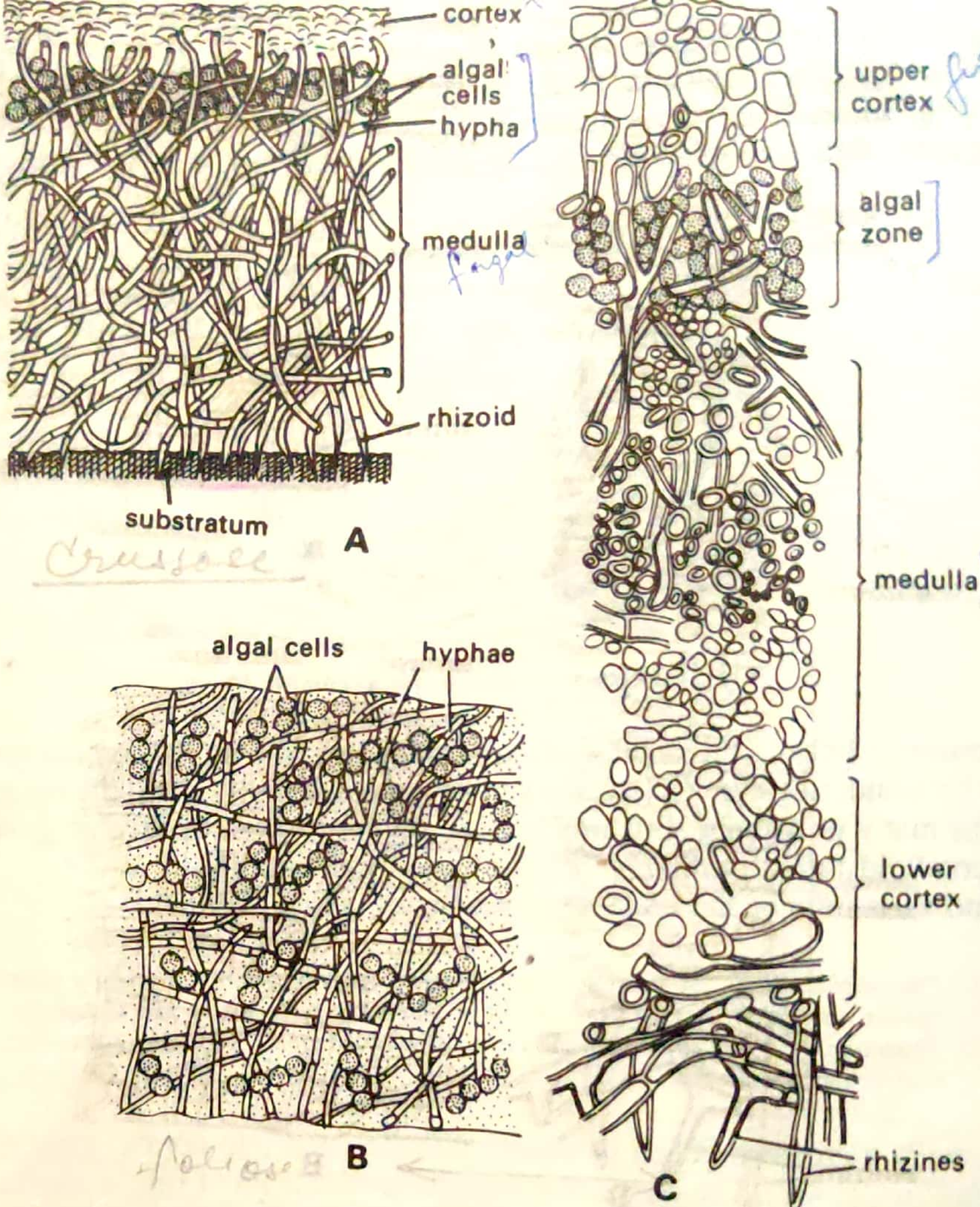

Fig. 21.4 Internal organisation of lichens A, Crustose lichen; B, foliose (homolomerous)lichen; C, foliose (heteromerous) lichen

4. *Fruticose lichens*: These are well-branched, generally erect or pendulous structures, which provide shruby appearance, e.g. *Usnea* (Fig.21.1C), *Cladonia* (Fig. 21.1*D,E*), *Letharia*, *Bryoria*, etc.

Internally the fruticose lichens have a heteromerous structure, which is not dorsiventral but develops around a vertical axis. The erect or pendulous nature of these lichens is maintained either because of the presence of a thickened outer cortex or by a specialized central elastic axis, called chondroid axis, as in *Usnea*.

5. *Filamentous lichens*: In all the above mentioned lichen types (leprose, crustose, foliose and fruticose) the fungus has the main role in the formation of the structure of the lichen thallus. But in some lichen genera (*Coenogonium*, *Ephebe*, *Racodium*, *Cystocoleus*) the algal partner is filamentous, well developed, and remains ensheathed or covered by only a few fungal hyphae. The lichen thalli so formed have the dominance of algal partner, and have been named *filamentous* by Hawksworth and Hill (1984).

21.7 TISSUE TYPES IN LICHENS

Not much is known about the tissue types in leprose, crustose and filamentous lichens. However, in foliose and fruticose lichens the fungal tissues are of taxonomic significance. According to Hawksworth and Hill (1984) the *cortex* in foliose and fruticose lichens consists of following two main type:

1. *Paraplectenchyma* : The cells are oriented randomly and provide a cellular appearance.
2. *Prosoplectenchyma:* The elongate fungal hyphae are oriented in a particular direction.

However, in some lichens (*Parmelia*), the cortex is overlined by a thin layer of polysaccharide, called '*epicortex*' (Hale, 1973).

Loosely interwoven hyphae, constituting the *medulla,* have been termed '*chalaroplectenchyma*' by Hawksworth and Hill (1984).

21.8 ATTACHMENT ORGANS IN LICHENS

Lichens remain attached to the substratum by following means:

1. *Medullary hyphae*: In the absence of lower cortex some fungal hyphae from the medulla (Fig. 21.4*A*) penetrate the substratum, e.g. a majority of the leprose and crustose lichens.
2. *Rhizinose strand*: These are complex, tough, irregularly branched thick strands, e.g. *Buellia pulchella* (Fig. 21.5 *A*).
3. *Hyphal net*: In *Psora decipiens* (Fig. 21.5 *B*) the fungal hyphae form delicate, reticulately branched net-like structures, called hyphal nets.
4. *Rhizines* : Simple, unbranched or branched attachment organs of foliose lichens are called rhizines (Fig.21.5 *C*).

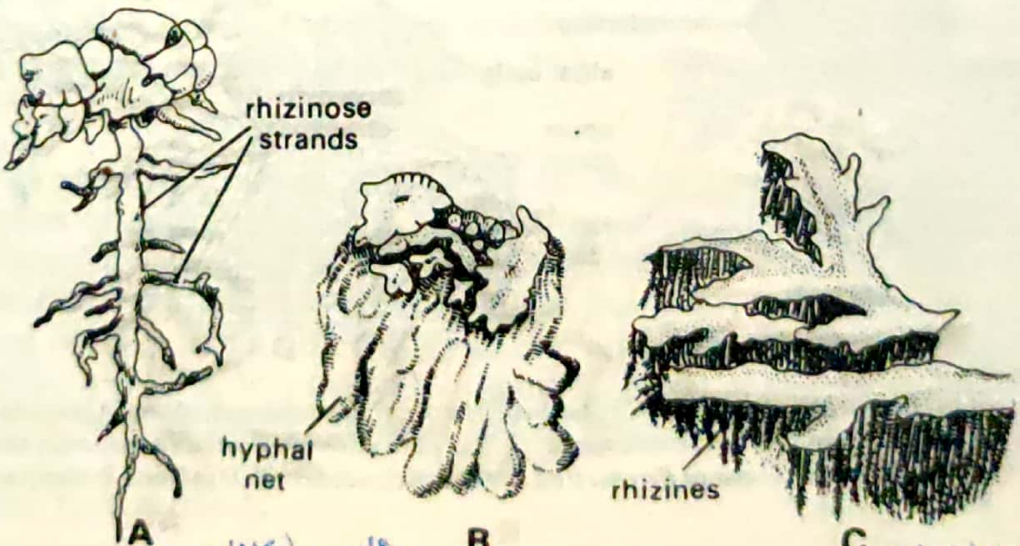

Fig.21.5 Attachment organs of some lichens. *A*, Rhizinose strand of *Buellia pulchella*; *B*, hyphal net of *Psora decipiens*; *C*, rhizines of *Physconia pulverulacea*

5. *Hypothallus* : A thick, black, spongy, algal-free tissue on the lower surface of genera, such as *Anzia*, is called *hypothallus*.
6. *Holdfast*: It is the basal, black, algal-free, persistent region of some lichens, such as *Usnea* and *Letharia*.
7. *Hapters*: These are the short, apical, penetrating branches of some large pendulous lichens which loose their attachment with the point of their origin, as in *Alectoria sarmentosa*.

21.9 PROPAGULES ASSOCIATED WITH LICHEN THALLUS

Along with the tissues already mentioned (such as upper cortex, algal layer, medulla, lower cortex, etc), some other vegetative structures (propagules) may also be associated with a lichen thallus . Some of these structures are breathing pores, cyphellae, pseudocyphellae, cephalodia, isidia and soredia.

Breathing Pores: These are the areas in the cortex where loosely interwoven (Smith, 1955) hyphae are present, e.g. *Oropogon*. Just below a breathing pore the tissue is more or less medullary in nature. Sometimes breathing pores are elevated in the form of a cone-like structure. In foliose lichens they develop only in the upper cortex. Breathing pores are supposed to function in gaseous exchange.

Cyphellae: These are the neat circular depressions present only on the lower surface of certain lichens, such as *Stricta* (Fig. 21.6 *A*). The depressed region of a cyphella remains lined by somewhat specialized rounded cells. The cyphellae play some role in facilitating gaseous exchange (Hawksworth and Hill, 1984).

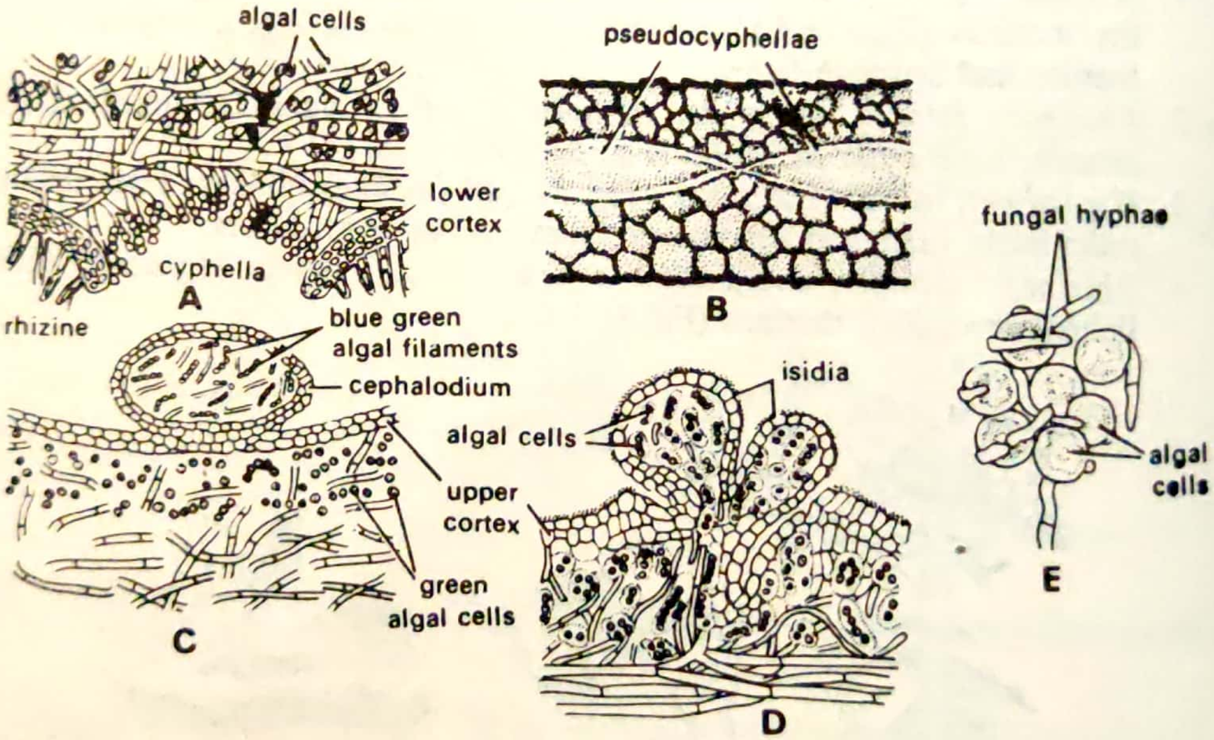

Fig.21.6 **Some lichen propagules. *A*, Cyphella of *Stricta*; *B*, pseudocyphellae of *Alectoria nigricans*; *C*, cephalodium of *Solorina crocea*; *D*, V.s. of thallus of *Parmelia conspersa*, showing two isidia; *E*, a soredium of *Parmelia* (*A*, after Schneider; *B*,*D*, after Ahmadjian; *C*, after Hawksworth)**

Pseudocyphellae: In genera such as *Alectoria*, *Bryoria*, *Coelocaulon* and *Pseudocyphellaria*, looser hyphal medullary tissue comes to the surface of the lichen thallus in the form of discrete patches, called *pseudocyphellae* (Fig. 21.6 *B*). These are also present on the lower surface. But in the region of pseudocyphellae the lower cortex is absent.

Cephalodia: Some of the lichens have two phycobionts, of which one is a blue-green alga and the another is a green alga. Such lichens, having three-membered symbiosis (2 algae + 1 fungus), are called 'diphycophilous lichens'. In such lichens the blue-green alga is segregated in special external or internal swellings

(Fig. 21.6*C*) called '*cephalodia*'. In diphycophylous lichens the main thallus is formed by the green alga. According to Hawksworth and Hill (1984) cephalodia are known to occur in 520 species of lichens, belonging to 21 genera of 8 families. Some of the cephalodia-producing lichens are *Lobaria amplissima*, *L.pulmonaria* and *Solorina crocea*.

Isidia : An isidium is a small and corticated outgrowth present on the upper surface of lichen thallus. It is made up of both fungal hyphae and algal cells (Fig. 21.6*D*).

Soredia : A soredium is a small but non-corticated bud-like outgrowth present on the upper surface of the lichen thallus. It is made up of only a few algal cells, enclosed by only a few fungal hyphae (Fig. 21.6*E*).

Both isidia and soredia contain mycobiont as well as phycobiont and are thus the means of the vegetative reproduction[1].

21.10 VEGETATIVE REPRODUCTION

21.10.1 Common methods

Fragmentation : In many foliose and fruticose lichens the thallus breaks into small fragments, each of which develops into new thallus under favourable conditions. Fragmentation is a major method of reproduction in fruticose lichens, such as *Cladonia uncialis*, *C.stellaris* and *Bryoria capillaris*.

Isidium : Small, corticated outgrowths, made up of both fungal hyphae and algal cells, and situated on the upper surface of the lichen thallus, are called *isidia* (Fig. 21.6*D*). The isidia are smooth, coral-, papilla-, scale-, or petal-like outgrowths (Hawksworth and Hill, 1984). They are constricted basally, and are easily broken away from the thallus. A detached isidium develops into a new lichen thallus. Isidia are common in genera such as *Parmelia* (Fig. 21.6*D*), *Pseudoevernia*, *Bryoria* and *Usnea*.

Soredium : As mentioned earlier, the soredia are small, non-corticated, bud-like, powdery masses or outgrowths, made up of only a few algal cells surrounded by only a few fungal hyphae (Fig. 21.6*E*). They develop either over the entire upper surface of the lichen thallus, or in special pustule-like areas, called '*soralia*'. Each soredium may develop into a new lichen thallus, provided satisfactory conditions of its growth are available. It is the most common method of vegetative reproduction in many lichens, including *Parmelia* and *Bryoria*.

21.10.2 Some rare methods

According to Hawksworth and Hill (1984), lichens may also reproduce rarely by any of the following methods of vegetative reproduction:

1. *Phyllidia* : These are abstricted, leaf-or scale-like, dorsiventral portions (Fig. 21.7*A*) of the entire thallus of some foliose lichens, e.g. *Peltigera praetextata*.
2. *Blastidia* : These are the yeast-like segmented propagules (Fig. 21.7 *B*) of *Physcia opuntiella*.
3. *Schizidia* : These are the splitted, scale-like segments of some lichens (*Parmelia taylorensis*) made up of the upper layers of the thallus (Fig. 21.7*C*).

[1] For more details see 'Vegetative Reproduction'

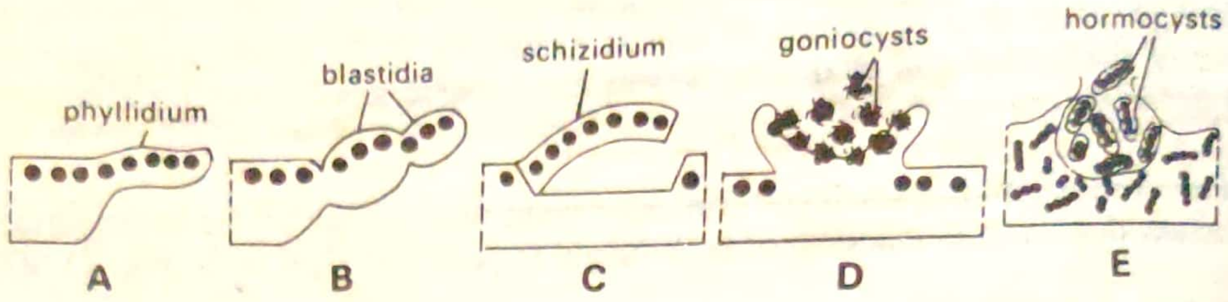

Fig.21.7 Diagrammatic representation of vegetative propagules of some lichens. *A, Phyllidium; B, Blastidium; C, Schizidium; D*, goniocyst; *E*, hormocyst

4. *Goniocysts* : When an algal cell and its derivatives remain wrapped in fungal hyphae in the form of an unsorallium-like structure, it is called a goniocyst (Fig. 21.7 *D*). These are formed in goniocystangia.
5. *Hormocysts* : When algal filaments and fungal hyphae grow together in a chain-like manner (Fig. 21.7*E*) and break into clumps, these are called hormocysts, e.g. many species of *Lempholema*.

21.11 ASEXUAL SPORES

21.11.1 Conidia

The conidia of different shape and size develop in special multihyphal structures in many lichens, such as *Anthonia* (Fig. 21.8 *B*), *Lecanactis, Peltigera* (Fig. 21.8 *C*), *Roccella* (Fig. 21.8*D*), *Cladonia* (Fig.21.8E), *Lobaria* (Fig. 21.8*F*) and

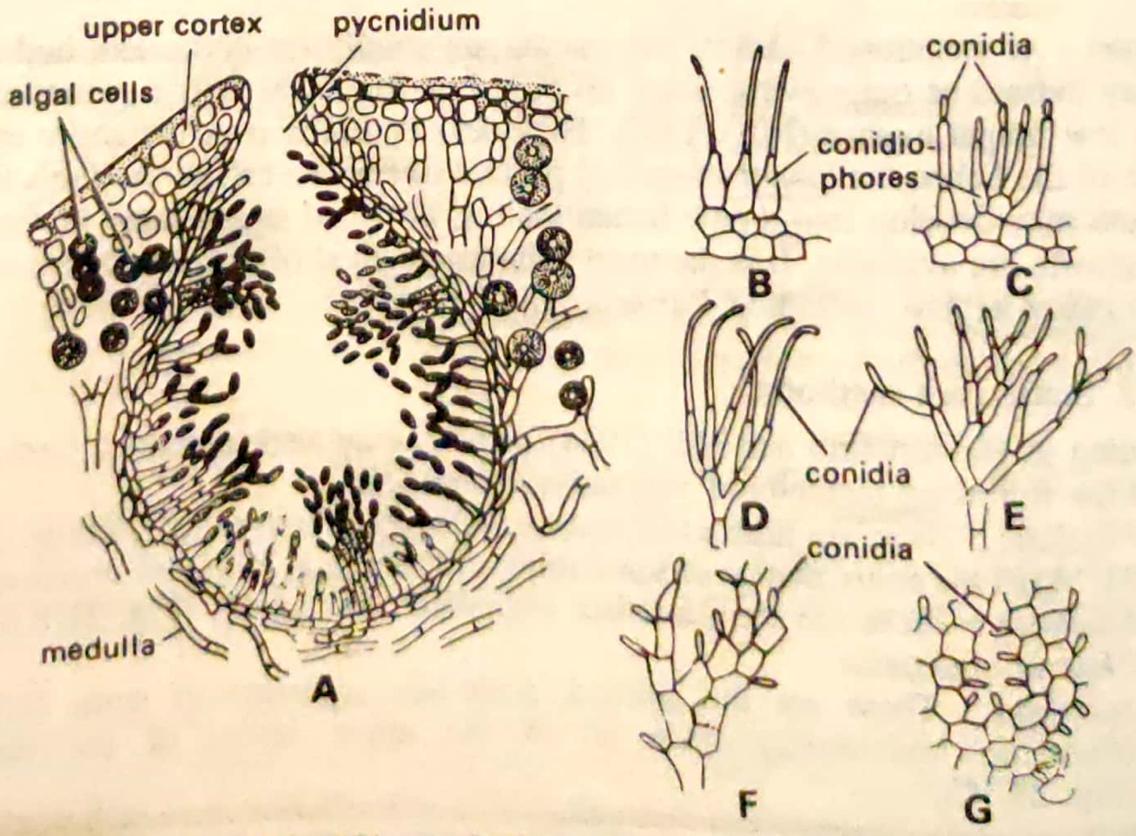

Fig.21.8A, V.S. of a pycnidium of *Physcia*; *B–G*, Conidia and conidiophores of *Arthonia* (*B*), *Peltigera* (*C*), *Roccella* (*D*), *Cladonia* (*E*), *Lobaria* (*F*) and *Xanthoria* (*G*)

Xanthoria (Fig. 21.8*G*). These conidia-containing multihyphal structures are termed '*conidiomata*' by Vobis and Hawksworth (1981). The conidiomata occur in many ascolichens. In the thallus the conidiomata always remain immersed in flask-shaped bodies, called *pycnidia*. A majority of the Deuterolichens reproduce only by producing conidia.

A pycnidium opens by a mouth-opening or ostiole (Fig.21. 8 *A*). From their inner lining wall develop some hyphae, called conidiophores. The conidia are produced either terminally, laterally or in an intercalary manner. The conidia so formed may be cylindrical, filiform or sickle-shaped.

The conidia are colourless and germinate by producing a germinating hypha. Such developing hyphae produce a lichen if they come in contact with an appropriate phycobiont.

Recently Honegger (1984) showed that in *Cladonia furcata* the conidia are attracted by the trichogyne and bring about fertilization. They have therefore a sexual role also to perform in some lichens.

21.11.2 Oidia

According to Smith (1921) the hyphae of certain lichens break up into small bodies, called oidia. The oidia may germinate into hyphae.

21.12 SEXUAL REPRODUCTION OF MYCOBIONT

21.12.1 In Ascolichens

Ascogonium : It develops from certain hyphae situated deep in the algal layer. The ascogonia are multicellular, and their lower portion is usually coiled (Fig. 21.9*A*). Usually the cells of the ascogonia are uninucleate. The upper portion of the multicellular ascogonium usually projects above the level of the cortex. Such projected portion represents *trichogyne*.

Spermatium : The conidia produced in pycnidia might also function as male cells (Honegger, 1984). Such conidia with a sexual function are called '*spermatia*' (Hawksworth and Hill,1984).

Fertilization : At the time of 'fertilization' many spermatia are lodged against the sticky tips of the trichogyne. Lichen thalli having many ascogonia but no spermatia do not show the production of ascocarps. This is also an indication that spermatia function as male gametes. Some of the empty spermatia are seen at the trichogyne tip, indicating that their protoplasts have migrated into the trichogyne. However, the actual migration of male nuclei into the trichogyne has not been observed (Smith, 1955).

The cytological processes involved in fertilization and further development of ascocarp are difficult to observe, mainly because the nuclei and chromosomes are minute.

Ascocarp : After fertilization many ascogenous hyphae develop from the basal portion of the ascogonium. At the ends of these freely branched ascogenous hyphae develop the asci. The crozier formation, development of the binucleate penultimate cell and its further development into an ascus have also been observed. Two nuclei of the ascus cell fuse to form a diploid nucleus. The latter divides and redivides to form eight haploid daughter nuclei. The asci are either unitunicate or bitunicate.

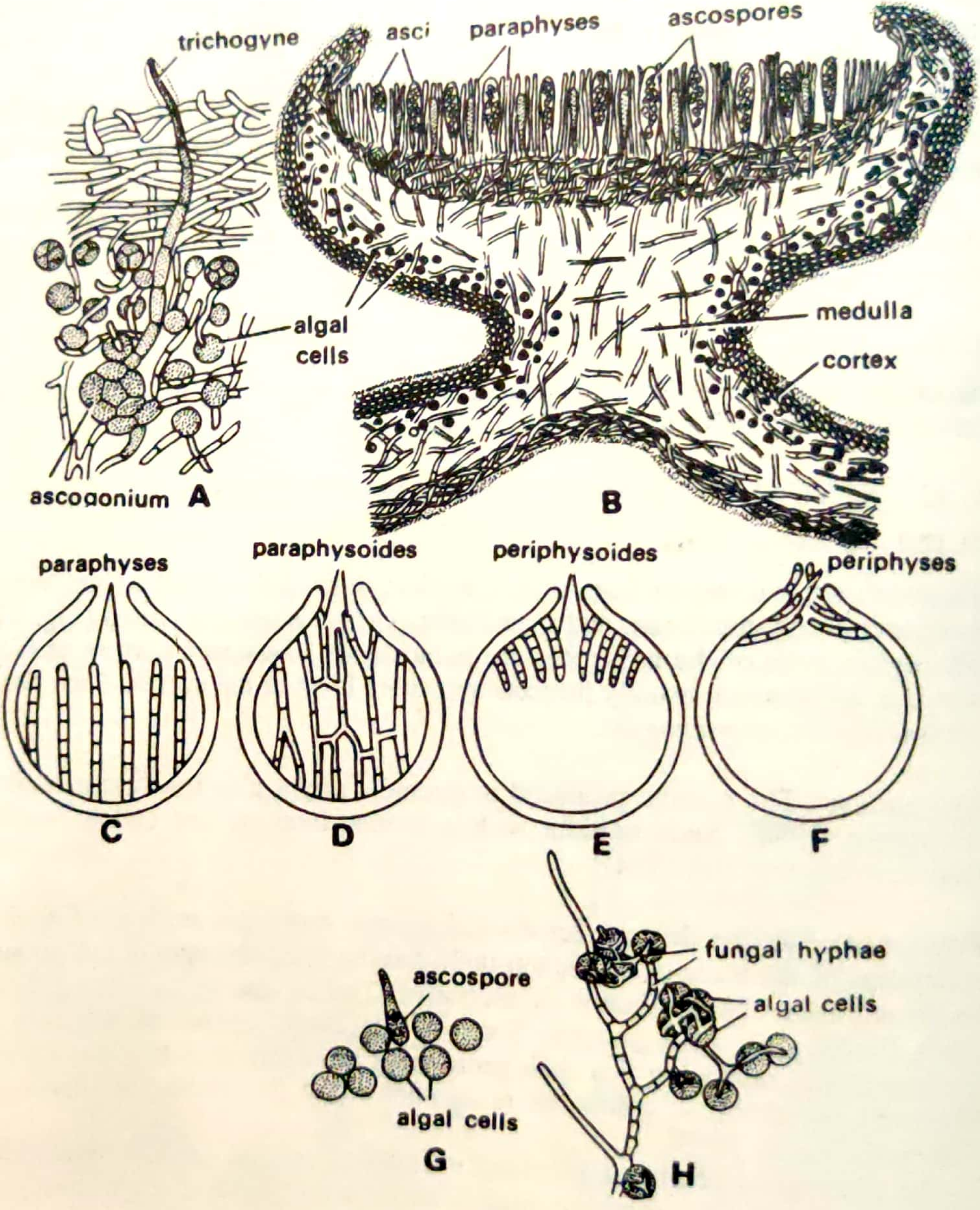

Fig. 21.9. *A*, Ascogonium with a protruding trichogyne of *Anaptychia ciliaris; B*, V.S. of an apothecium of *Physcia; C-F*, hamathecium types, i.e. paraphyses *(C)*, paraphysoides *(D)*, periphysoids *(E)*, periphyses *(F)* ; *G*, a germinating ascospore of *Physcia parietina* along with the cells of the alga *Trebouxia;* H, formation of the lichen thallus

These ascus-bearing structures are named '*ascomata*' (Hawksworth and Hill, 1984). The ascomata or ascocarps may be either of *apothecium* (Fig. 21.9*B*) or *perithecium* type. The apothecium is a cup-shaped fruiting body, whereas perithecium is a flask-shaped structure. The hymenium or ascus-bearing tissue is exposed at maturity in apothecia, whereas the asci are borne within a locule in perithecium. The apothecia are produced commonly in species of *Lacidella, Arthonia, Graphis, Physcia* (Fig. 21.9*B*),*Baeomyces, Umbilicaria* etc., whereas the perithecia are produced in species of *Pyrenula, Verrucaria, Acrocordia* etc.

Hamathecia : The tissues that separate the asci are called '*hamathecia*', (Hawksworth and Hill, 1984). According to Eriksson (1981) the hamathecial elements may be any of the following types:

1. *Paraphyses* : These originate from the base of the ascocarp and grow upwards (Fig. 21.9*C*)
2. *Paraphysoides* : These originate from the stretching of the tissues of the ascocarp before the development of asci (Fig. 21.9 *D*)
3. *Periphysoids* : These originate from above the asci, and grow downwards (Fig. 21.9*E*)
4. *Periphyses* : These line the ostiolar canal and grow upwards (Fig. 21.9*F*)

Ascospores : Usually eight ascospores are produced in each ascus. The latter is either unitunicate or bitunicate. The ascospores vary greatly in shape, size, structure and septation. They may be greenish, brown or even colourless. They may be unicellular, have transverse septa, or have both transverse as well as longitudinal septa. In size the ascospores vary from 1 μm to 500 μm

Synthesis of lichen thallus : The ascospores are discharged and start germination by producing hyphal branches. A hyphal branch comes in contact with a suitable alga (Fig. 21.9 *G,H*), and the combined growth of the fungus and the alga eventually results in a lichen thallus. The hyphal branches die after sometime if they do not come in contact with a suitable alga.

21.12.2 In Basidiolichens

About 20 species of Basidiolichens are known, but reproductive cycle has not been investigated in any of them (Letrouit-Galinou, 1973). However, it is presumed that basidiospores are formed in the same way as in other non-lichenized basidiomycetous fungi. The mycobiont in Basidiolichens mainly belong to Aphyllophorales or Agaricales.

21.13 REPRODUCTION IN PHYCOBIONT

Phycobionts belonging to blue-green algae reproduce by akinetes, hormogonia, heterocysts and cell-division, when grown in laboratory. The green-algal phycobionts are known to muliply by vegetative cell division, and formation of aplanospores and biflagellate zoospores (Ahmadjian, 1967; Slocum *et al.*,1980). The sexual reproduction in phycobionts has not been observed in nature (Hawksworth and Hill, 1984).

21.14 ECONOMIC IMPORTANCE

Biochemical weathering and pedogenesis: The crustose lichens affect the chemistry of the rocks on which they grow, by producing a series of activities. These activities are collectively called '*biological weathering*'. The activities are mainly because of the secretion of some soluble organic acids by the mycobiont. The main organic acid is oxalic acid, which causes surface etching and ultimately disintegrate the rocks over which the lichens are growing (Syers and Iskander, 1973).

This surface etching by oxalic acid first produces honeycomb-like structures on the rocks, and then disintegration of rocks into finer particles of soil. The process of the formation of this new soil is called '*pedogenesis*'. Dead organic remains of the thalli mix with these fine particles of the new soil, which ultimately becomes fertile enough for other plants to grow.

Natural products : Lichens are known to produce over 550 natural products, including lecanoric acid, salazinic acid, squamatic acid, physcion, rhizocarpic acid, calycin, usnic acid, lichenin, zeorin, and many other aliphatic acids, benzyl esters, xanthones, terpenoids etc. (Culberson, 1969; Culberson and Ahmadjian, 1980; Hawksworth and Hill,1984). Salazinic acid is produced from *Ramalina siliquosa*, squamatic acid from *Cladonia crispata* , and lecanoric acid from *Parmelia subrudecta*.

Drugs from lichens : Some lichens are useful as drugs, as shown by the following examples:

1. Usnic acids, produced from many lichens, have antibiotic properties, and are effective against many Gram-positive bacteria.
2. Many antiseptic creams, such as '*Usno*' and '*Evosin*' are available in the market, and well-known for their tumour-inhibiting, spasmolytic and virucidal properties.
3. Erythrin, obtained from *Roccella montagnei*, is used in angina, a serious *heart disease*.
4. Some lichens have protolichesterinic acid, a compound used in the preparation of some *anti-cancer drugs*.
5. Some lichen compounds (lichenin and isolichenin) have *anti-tumour* properties.
6. Use of *Lobaria pulmonaria* and *Cetaria islandica* in tuberculosis and other lung diseases is known since very early times.
7. Some lichens are used with tobacco because of their hallucinogenic effects.

Perfumes from lichens : *Pseudevernia furfuracea* and *Evernia prunastri* are widely used in the manufacture of perfumes. The remainder, left after the preparation of perfumes from lichens, contains compounds such as naphthalene, camphor, geraniol and borneol.

Dyes from lichens : Red and purple dyes are obtained from *Ochrolechia androgyna* and *O. tartaria*. '*Litmus paper*', used as an acid-base indicator in the laboratories, is prepared from lichens, such as *Roccella montagnei* and *Lasallia pustulata*. The lichen compounds that are responsible for these colours are lecanoric acid, erythrin and gyrophoric acid.

Brown dye is obtained from *Parmelia omphalodes*. They are used to dye wool and silk fibres.

Food from lichens : *Cladonia rangiferina* (reindeer moss) serves as a common food in Tundra regions for many animals, including reindeer and musk ox. '*Reindeer* *moss*' grows very slowly, at less than 1 cm/year in the arctic tundra regions. According to some unsubstantiated records, the lichen thalli in the arctic may be up to 4000 years old. Species of *Parmelia, Lecanora* and *Cetraria* are eaten by man horses, cattles etc. in some form or other.

Materials for religious purposes from lichens : Lichens used in the preparation of perfumes are also used in the manufacture of '*dhoop* and '*havan samagries,* used at the time of religious ceremonics.

Poison from lichens : *Letharia vulpina* (*wolf moss*) is used as a poison for wolves when mixed with powdered glass. Vulpinic acid, present in this lichen, is responsible for its poisonous nature.