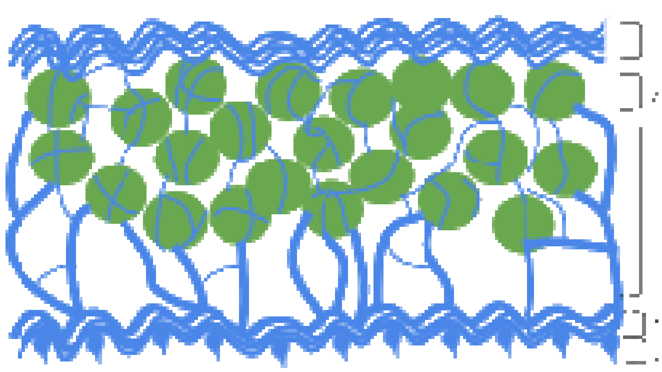
Lichen

Definition: A lichen is an association of a fungus and a photosynthetic symbiont, resulting in a stable thallus of specific structure. A **lichen** is a composite organism that arises from algae or cyanobacteria (or both) living among filaments of a fungus in a symbiotic relationship. The combined life form has properties that are very different from the properties of its component organisms. Lichens come in many colors, sizes, and forms. The properties are sometimes plant-like, but lichens are not plants. Lichens may have tiny, leafless branches (fruticose), flat leaf-like structures (foliose), flakes that lie on the surface like peeling paint (crustose), or other growth forms. Lichens do not have roots that absorb water and nutrients as plants do but like plants they produce their own food by photosynthesis using sunlight energy, from carbon dioxide, water and minerals in their environment. When they grow on plants, they do not live as parasites and only use the plants as a substrate.

Internal structure

A lichen is made up of a simple photosynthesizing organism, usually green algae or cyanobacteria, surrounded by filaments of a fungus. Generally, most of a lichen's bulk is made of interwoven fungal filaments, although in filamentous and gelatinous lichens this is not the case. The fungus is called a **mycobiont**. The photosynthesizing organism is called a **photobiont**. Algal photobionts are called **phycobionts**. Cyanobacteria photobionts are called **cyanobionts**.

The part of a lichen that is not involved in reproduction, the "body" or "vegetative tissue" of a lichen, is called the **thallus**. The thallus form is very different from any form where the fungus or alga are growing separately. The thallus is made up of filaments of the fungus called **hyphae**. The filaments grow by branching then rejoining to create a mesh, which is called being "anastomose". The mesh of fungal filaments may be dense or loose.



Schematic cross section of foliose lichen: 1. The cortex is the outer layer of tightly woven fungus filaments (hyphae) 2. This photobiont layer has photosynthesizing green algae 3. Loosely packed hyphae in the medulla 4. A tightly woven lower cortex, with anchoring hyphae called rhizines where the fungus attaches to the substrate.

Growth forms:

The following are common growth forms of lichens:

1. **Leprose** (powdery) –This is the simplest type of thallus organization, in which the fungal hyphae envelope either single or small cluster of algal cells. The thallus is a layer so thin that it is almost like a powder stuck to the substrate, e.g. *Leprararia incana.*

2. **Crustose** lichens (paint-like, flat, 2-dimensional, upper cortex, no lower cortex), e.g., The thallus lies flat and tightly bound at all points to the substrate, like it is painted on.In these lichens, the thallus is very closely adhered to the substratum and provides crust like appearance, e.g. *Caloplaca thallincola*.

3. **Foliose** (leafy, 2-dimensional planes, two cortices – upper and lower – The thallus is flat, leaf-like, lobed, well-branched and attached to the substratum with the help of rhizoid like rhizines.), e.g., *Parmelia, Collema, Peltigera* etc.

4. **Fruticose** (branched, 3-dimiensional, one cortex surrounds thallus), *C. subtenuis*, and - The thallus is well branched, extended up or hangs down, in a branched or tufted structure, which provides shrubby appearance e.g., *Cladonia* , *Usnea* , *Letharia etc.*

4. **Filamentous** (hairlike), – The thallus forms mostly nonbranching hair-like structures that may look overall like matted hair.The algal partner is filamentous, well-developed, and remains ensheathed by onla a few fungal hyphae e.g., *Ephebe* , *Cystocoleus etc.*

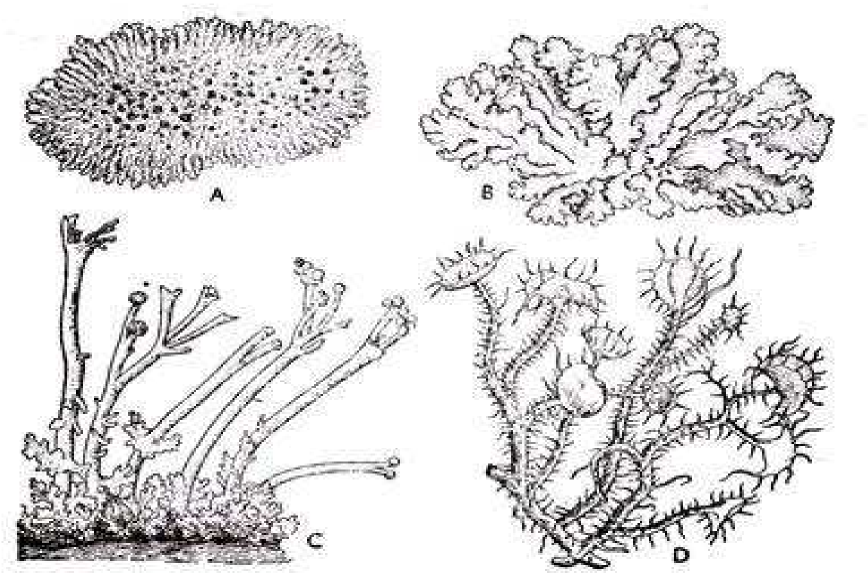


Fig. 315. Different forms of lichens. A. Crustose in *Graphis* sp. B. Foliose in *Parmelia* sp. C. Fruticose with a much-branched ribbon-like thallus bearing erect or pendant fruiting portion in *Cladonia* sp. D. Fruticose in *Usnea* sp.

5. **Squamulose** (scale-like or platelet-like, upper cortex but no lower cortex under raised portion), - The thallus is composed of mostly flat laying, overlapping, scale-like plates ("squamules"), which may become leaf-like in form where they are not attached to the substrate, but which do not have a lower cortex on the underside. Some lichenologists consider squamulous lichens to be a special kind of crustose lichen e.g., *Normandina* .

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.

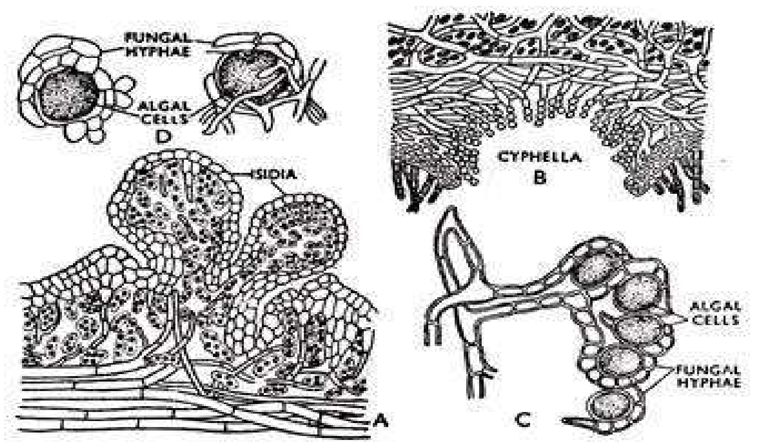


Fig. 318. Specialized structures of lichen thallus. A. Isidia of *Peltigera* sp. B. Cyphella of *Sticta* sp. C. Portion of algal layer showing association between fungal hyphae and algal cells. D. Soredia of *Physcia pulverulenta* and *Ramalina farinacea*.

(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.

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.

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.

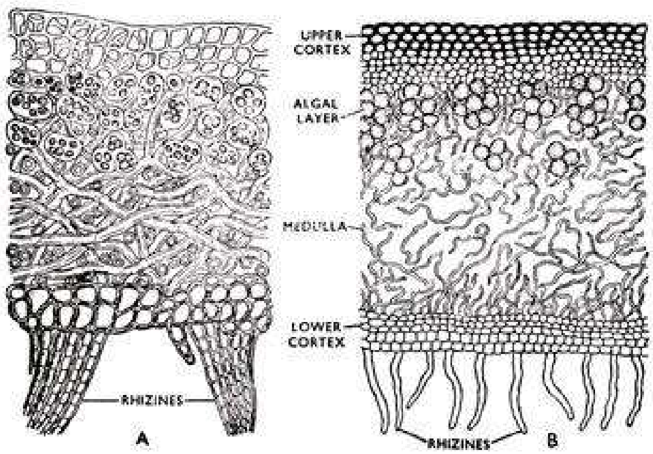


Fig. 316. Structural details of lichen thalli in section. A. Upper cortex with intercellular spaces. B. Upper cortex without intercellular spaces.

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).

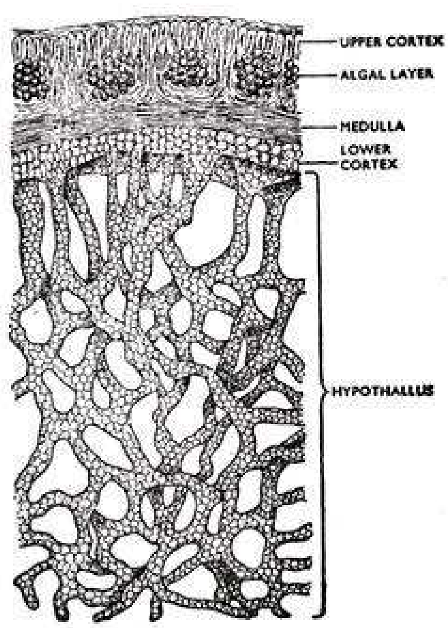


Fig. 317. *Pannoparmelia anzioides.* Vertical section of thallus and hypothallus.

(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

Economic Importance of Lichens

Lichens are useful to human life in various ways: as food and fodder, as medicine and industrial uses of various kinds.

Food for Human Being:

Lichens contain lichenin, a carbohydrate very much allied to starch; cellulose, vitamin and certain enzymes. *Cetraria islandica*, the commercial 'Iceland Moss' is supplied from Sweden, Norway or Iceland is used as food by man.Species of *Umbillicaria, Parmelia* and *Leonora* are used as food in different parts of the world. 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.

Use as fodder:

Many lichens are used 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 rangifera*, the Well-known 'reindeer moss', is the lichen most favourite as food for reindeer, cattle, etc.

Source of Medicine:

Lichens owe their repute as curative herb to the presence of lichenin in the thallus and of some bitter or astringent substances, which, in various ailments, proved of real service to the patient. Lichens have been used in the treatment of jaundice, diarrhoea, fevers, epilepsy, hydrophobia, and skin diseases. In Iceland, lichen is used as a laxative. A preparation of *Peltigera canina* has been used to cure hydrophobia. *Parmelia saxatilis*, the 'skull lichen' has a medicinal property which can cure epilepsy. *Cetraria islandica* and *Lobaria pulmonaria* are used for tuberculosis and other lung diseases, *Parmelia sexatilis* for epilepsy; *Parmelia perlata* for dyspepsia; *Cladonia pyxidata* for whooping cough and *Xanthoria perietina* for jaundice. 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.

For 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. The blue dye 'Orchil' obtained from *Cetraria islandica* and others, is used for dyeing woollen goods. **Orcein**, the active principal content of orchil-dye, is used extensively in laborator during histological studies and for dyeing coir.

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.Litmus is also obtained from *Roccella montagnei* and also from *Lasllia pustulata.*

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 due to rich content of lichenin.

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 *Pseudovernia furfuracea*. 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 thalli of species of *Usnea* possess the power of retaining scent, and are profitably utilized in perfumery. Powdered thallus of *Ramalina calicaris* is often used to whiten hair wigs.

Essential oils extracted from species of *Evernia* and *Ramalina* are used in the manufacture of cosmetic soap.

Ecological Importance of Lichens

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.

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.

Sensitivity to air pollutants:

Lichens are very much sensitive to air pollutants like SO_2, CO,CO_2 etc.; thereby the number of lichen thalli in the polluted area is gradually reduced and ultimately comes down to nil.The crustose lichens can tolerate much more in polluted area than the other two types. For the above facts, the lichens are markedly absent in cities and industrial areas. Thus, lichens are used as ‘pollution indicators’.

Accumulation of radioactive substance:

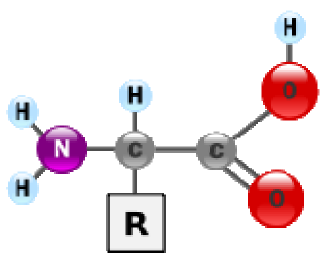
Lichens are efficient for absorption of different radioactive substances. The *Cladonia rangiferina* the ‘reindeer moss’ and *Cetraria islandica* the ‘iceland moss’ are the commonly available lichens in Tundra region. The fallout of radioactive strontium (^{90}Sr) and caesium(^{137}Cs) from the atomic research centres are absorbed by lichen. Thus, lichen can purify the atmosphere from radioactive substances.

Proteins

Proteins are large biomolecules, or macromolecules, consisting of one or more long chains of amino acid residues. Proteins perform a vast array of functions within organisms, including catalysing metabolic reactions, DNA replication, responding to stimuli, and transporting molecules from one location to another. Proteins differ from one another primarily in their sequence of amino acids, which is dictated by the nucleotide sequence of their genes, and which usually results in protein folding into a specific three-dimensional structure that determines its activity.

A linear chain of amino acid residues is called a polypeptide. A protein contains at least one long polypeptide. Short polypeptides, containing less than 20–30 residues, are rarely considered to be proteins and are commonly called peptides, or sometimes oligopeptides. The individual amino acid residues are bonded together by peptide bonds and adjacent amino acid residues. In general, the genetic code specifies 20 standard amino acids.

Amino acids are biologically important organic compounds containing amine (-NH_2) and carboxylic acid (-COOH) functional groups, usually along with a side-chain (R group) specific to each amino acid. The key elements of an amino acid are carbon, hydrogen, oxygen, and nitrogen, though other elements are found in the side-chains of certain amino acids. About 500 amino acids are known (though only 20 appear in the genetic code) and can be classified in many ways. They can be classified according to the core structural functional groups' locations as alpha- (α-), beta- (β-), gamma- (γ-) or delta- (δ-) amino acids; other categories relate to polarity, pH level, and side-chain group type (aliphatic, acyclic, aromatic, containing hydroxyl or sulfur, etc.). Outside proteins, amino acids perform critical roles in processes such as neurotransmitter transport and biosynthesis.



Srtructure of an amino acid

In the structure shown above, **R** represents a side-chain specific to each amino acid. The carbon atom next to the carboxyl group (which is therefore numbered 2 in the carbon chain starting from that functional group) is called the α–carbon. Amino acids containing an amino group bonded directly to the alpha carbon are referred to as *alpha amino acids*. These include amino acids such as proline which contain secondary amines, which used to be often referred to as "imino acids"

Proteins are macromolecules and have four different **levels of structure** – primary, secondary, tertiary and quaternary.

Primary Structure

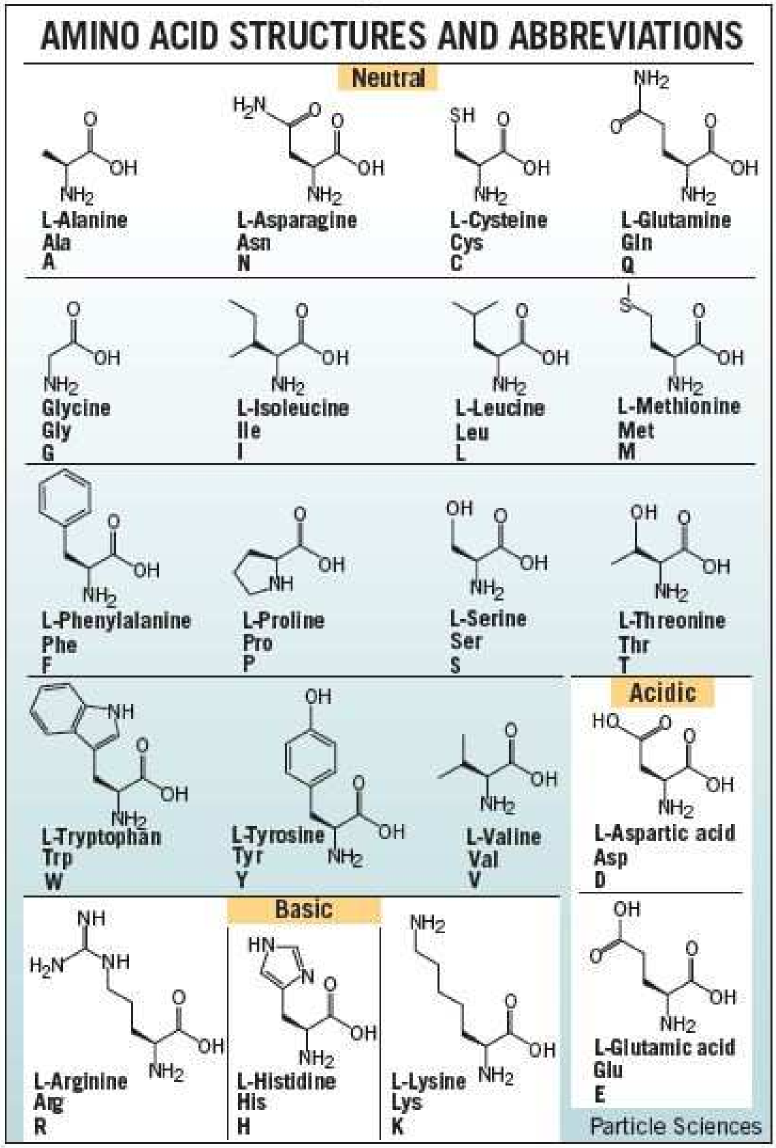


Figure 1

There are 20 different standard L-α-amino acids used by cells for protein construction. Amino acids, as their name indicates, contain both a basic amino group and an acidic carboxyl group. This difunctionality allows the individual amino acids to join together in long chains by forming *peptide bonds:* amide bonds between the -NH2 of one amino acid and the -COOH of another. Sequences with fewer than 50 amino acids are generally referred to as *peptides*, while the terms *protein* or *polypeptide* are used for longer sequences. A protein can be made up of one or more polypeptide molecules. The end of the peptide or protein sequence with a free carboxyl group is called the *carboxy-terminus* or *C-terminus*. The terms *amino-terminus* or *N-terminus* describe the end of the sequence with a free α-amino group.

The amino acids differ in structure by the substituent on their side chains. These side chains confer different chemical, physical and structural properties to the final peptide or protein. The structures of the 20 amino acids commonly found in proteins are shown in Figure 1. Each amino acid has both a one-letter and three-letter abbreviation. These abbreviations are commonly used to simplify the written sequence of a peptide or protein.

Depending on the side-chain substituent, an amino acid can be classified as being acidic, basic or neutral. Although 20 amino acids are required for synthesis of various proteins found in humans, we can synthesize only 10. The remaining 10 are called essential amino acids and must be obtained in the diet.

The amino acid sequence of a protein is encoded in DNA. Proteins are synthesized by a series of steps called transcription (the use of a DNA strand to make a complimentary messenger RNA strand - mRNA) and translation (the mRNA sequence is used as a template to guide the synthesis of the chain of amino acids which make up the protein). Often, post-translational modifications, such as glycosylation or phosphorylation, occur which are necessary for the biological function of the protein. While the amino acid sequence makes up the ***primary structure*** of the protein, the chemical/biological properties of the protein are very much dependent on the three-dimensional or tertiary structure.

Secondary Structure

Stretches or strands of proteins or peptides have distinct characteristic local structural conformations or ***secondary structure***, dependent on hydrogen bonding. The two main types of secondary structure are the α-helix and the ß-sheet.

The *α-helix* is a right-handed coiled strand. The side-chain substituents of the amino acid groups in an α-helix extend to the outside. Hydrogen bonds form between the oxygen of the C=O of each peptide bond in the strand and the hydrogen of the N-H group of the peptide bond four amino acids below it in the helix. The hydrogen bonds make this structure especially stable. The side-chain substituents of the amino acids fit in beside the N-H groups.

The hydrogen bonding in a *ß-sheet* is between strands (inter-strand) rather than within strands (intra-strand). The sheet conformation consists of pairs of strands lying side-by-side. The carbonyl oxygens in one strand hydrogen bond with the amino hydrogens of the adjacent strand. The two strands can be either parallel or anti-parallel depending on whether the strand directions (N-terminus to C-terminus) are the same or opposite. The anti-parallel ß-sheet is more stable due to the more well-aligned hydrogen bonds.

Tertiary Structure

The overall three-dimensional shape of an entire protein molecule is the ***tertiary structure***. The protein molecule will bend and twist in such a way as to achieve maximum stability or lowest energy state. Although the three-dimensional shape of a protein may seem irregular and random, it is fashioned by many stabilizing forces due to bonding interactions between the side-chain groups of the amino acids.

Under physiologic conditions, the hydrophobic side-chains of neutral, non-polar amino acids such as phenylalanine or isoleucine tend to be buried on the interior of the protein molecule thereby shielding them from the aqueous medium. The alkyl groups of alanine, valine, leucine and isoleucine often form hydrophobic interactions between one-another, while aromatic groups such as those of phenylalanine and tryosine often stack together. Acidic or basic amino acid side-chains will generally be exposed on the surface of the protein as they are hydrophilic.

The formation of disulfide bridges by oxidation of the sulfhydryl groups on cysteine is an important aspect of the stabilization of protein tertiary structure, allowing different parts of the protein chain to be held together covalently. Additionally, hydrogen bonds may form between different side-chain groups. As with *disulfide bridges*, these hydrogen bonds can bring together two parts of a chain that are some distance away in terms of sequence. *Salt bridges*, ionic interactions between positively and negatively charged sites on amino acid side chains, also help to stabilize the tertiary structure of a protein.

Quaternary Structure

Many proteins are made up of multiple polypeptide chains, often referred to as *protein subunits*. These subunits may be the same (as in a homodimer) or different (as in a heterodimer). The ***quaternary structure*** refers to how these protein subunits interact with each other and arrange themselves to form a larger aggregate protein complex. The final shape of the protein complex is once again stabilized by various interactions, including hydrogen-bonding, disulfide-bridges and salt bridges.The four levels of protein structure are shown in Figure 2.

Figure 2