18BBO25A- PLANT STRUCTURE AND FUNCTIONS (FOR ZOOLOGY STUDENTS) Handled by Dr.J.Jayachithra

Unit - V

Ecology - Factors of Environment (Abiotic and Biotic Factors), Morphological and

Anatomical adaptations of Hydrophytes (*Hydrilla)* and Xerophytes (*Nerium*)

Phytogeography- Vegetation types of India.

Abiotic and Biotic Factors

Many factors influence every part of our environment: things like how tall trees grow, where animals and plants are found, and why birds migrate. There are two categories of these factors: abiotic and biotic.

Abiotic factors are the non-living parts of the environment that can often have a major influence on living organisms. Abiotic factors include water, sunlight, oxygen, soil and temperature.

Water (H_2O) is a very important abiotic factor – it is often said that “water is life.” All living organisms need water. Plants must have water to grow. Even plants that live in the desert need a little bit of water to grow. Without water, animals become weak and confused, and they can die if they do not rehydrate. Think of how you feel after you take a long run. Do you feel thirsty? This is your body signaling to you that you must rehydrate.

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Sunlight is the main source of energy on Earth, which makes it an extremely important abiotic factor. Sunlight is necessary for photosynthesis, the process by which plants convert carbon dioxide (CO_2) and water to oxygen (O_2) and sugar – food for the plants that later becomes food for animals. Without the sun, plants could not live, and without plants, animals could not live! The sun’s heat is also extremely important – see the section on Temperature below.

Like water, **oxygen** (O_2) is another important abiotic factor for many living organisms. Without oxygen, humans would not be able to live! This is true for the many other living organisms that use oxygen. Oxygen is produced by green plants through the process of photosynthesis, and is therefore directly linked to sunlight.

Soil is often considered an abiotic factor since it is mostly made up of small particles of rock (sand and clay) mixed with decomposed plants and animals. Plants use their roots to get water and nutrients from the soil. Soils are different from place to place – this can be a big factor in which plants and animals live in a certain area.

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Temperature is an abiotic factor that is strongly influenced by sunlight. Temperature plays an important role for animals that cannot regulate their own body temperature, such as reptiles. Unlike humans, whose normal body temperature is usually around 98.6°F, reptiles (such as snakes and lizards) cannot maintain a constant body temperature. Reptiles are usually found in warm regions around the planet. To regulate their body temperatures, reptiles will sun themselves on rocks, which absorb heat from sunlight and then radiate heat back into the environment.

Biotic factors are all of the living things in an ecosystem, such as plants and animals. These living things interact with one another in many ways. Biotic factors and their interactions can be broken down into three groups:

1. **Producers**. All plants, such as grass and trees, are producers. These organisms absorb the sun's energy and convert the energy into food for themselves, allowing them to grow larger, make flowers and seeds, etc.
2. **Consumers**. These organisms, mostly animals, eat producers and/or other animals. They may also eat decomposers. Two examples of consumers are deer (eat plants) and wolves (eat animals). Consumers that only eat plants (herbivores) are often known as primary consumers.
3. **Decomposers**. These organisms break down dead material (such as a fallen tree) into soil and return nutrients to the soil so they can be re-used by producers to create food. An example of a decomposer is a mushroom.

Ecological Adaptation of Plants

On the basis of their water requirement and nature of soils, the plants have been classified as follows:

1. Hydrophytes:

Plants growing in or near water.

2. Xerophytes:
Plants adapted to survive under the condition of very poor supply of available water in the habitats.

3. Mesophytes:
Plants growing in an environment which is neither very dry nor very wet. The detailed description of only some important ecological groups is given here.

Hydrophytes:
(Greek, Hudor = water and Phyton = Plant; water plant):
Plants which grow in wet places or in water either partly or wholly submerged are called hydrophytes or aquatic plants. Examples are *Utricularia. Vallisneria, Hydrilla Chara Nitella Lotus*, *Ceratophyllum, Trapa, Pistia*, *Eichhornia (water hyacinth), Wolffia*, *Lemna*, etc
Aquatic environment provides a matrix for plant growth in which temperature fluctuation is at minimum and the nutrients occur mostly in dissolved state but light and oxygen become deficient with the increase m depth of water bodies. Zonation of aquatic vegetation with increasing depth is a device for maximum utilization of light energy.

The aquatic environment is subject to water movements ranging from small vertical circulation to strong currents. Streams have a unidirectional movement and m seas the movement is reversible. The currents of water often abrade the inhabiting flora and varied modifications are encountered to withstand this abrasive action. Since water makes up a large proportion of the bodies of plants and animals (70 to 90% water in protoplasm), it affects all life processes directly.

In plants, the rate and magnitude of the photosynthesis, respiration absorption of nutrients, growth and other metabolic processes are influenced by the amount of available water. Low relative humidity increases water loss through transpiration and affects plant growth. Conversely, plants in the regions with high moisture show reduced transpiration.

Some aquatic groups of higher plants probably originated from mesophytes. In the course of evolution several changes m the physiology, morphology and behaviour, all related to the aquatic mode of life, took place and by these evolutionary changes the mesophytic plants have become adapted to aquatic mode of life.

Classification of Hydrophytes:
According to their relation to water and air, the hydrophytes are grouped into the following categories:
(a) Submerged hydrophytes

(b) Floating hydrophytes

(c) Amphibious hydrophytes.

(a) Submerged hydrophytes:
Plants which grow below the water surface and are not in contact with atmosphere are called submerged hydrophytes. Such plants may be free-floating (Fig 8.1) or rooted (Fig. 8.2). Example Vallisneria, Hydrilla, Potamogeton, Najas. Ceratophyllum Mynophyllum, Utricularia, Chara, Nitella and a number of aquatic microbes.

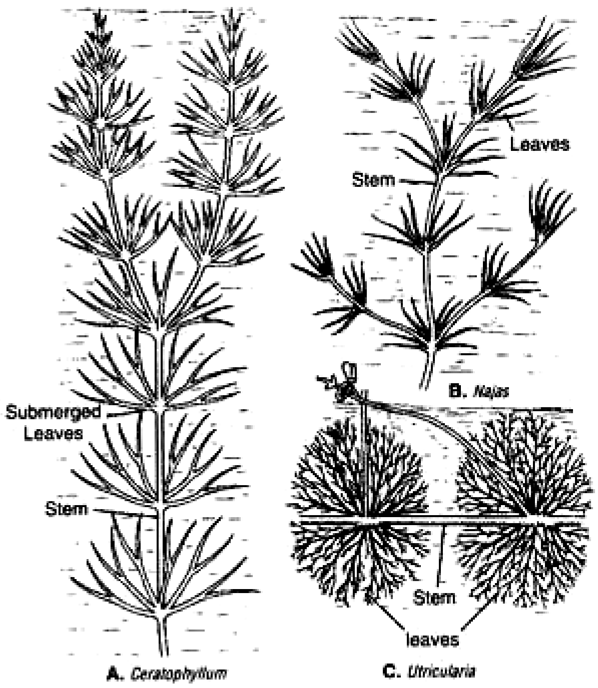

Fig. 8.1. Submerged floating hydrophytes.

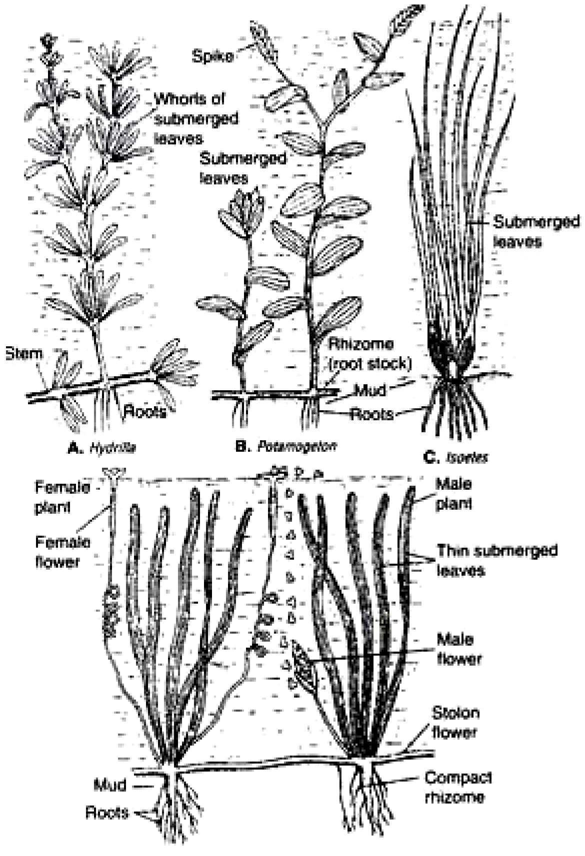

Fig. 8.2. Rooted submerged hydrophytes

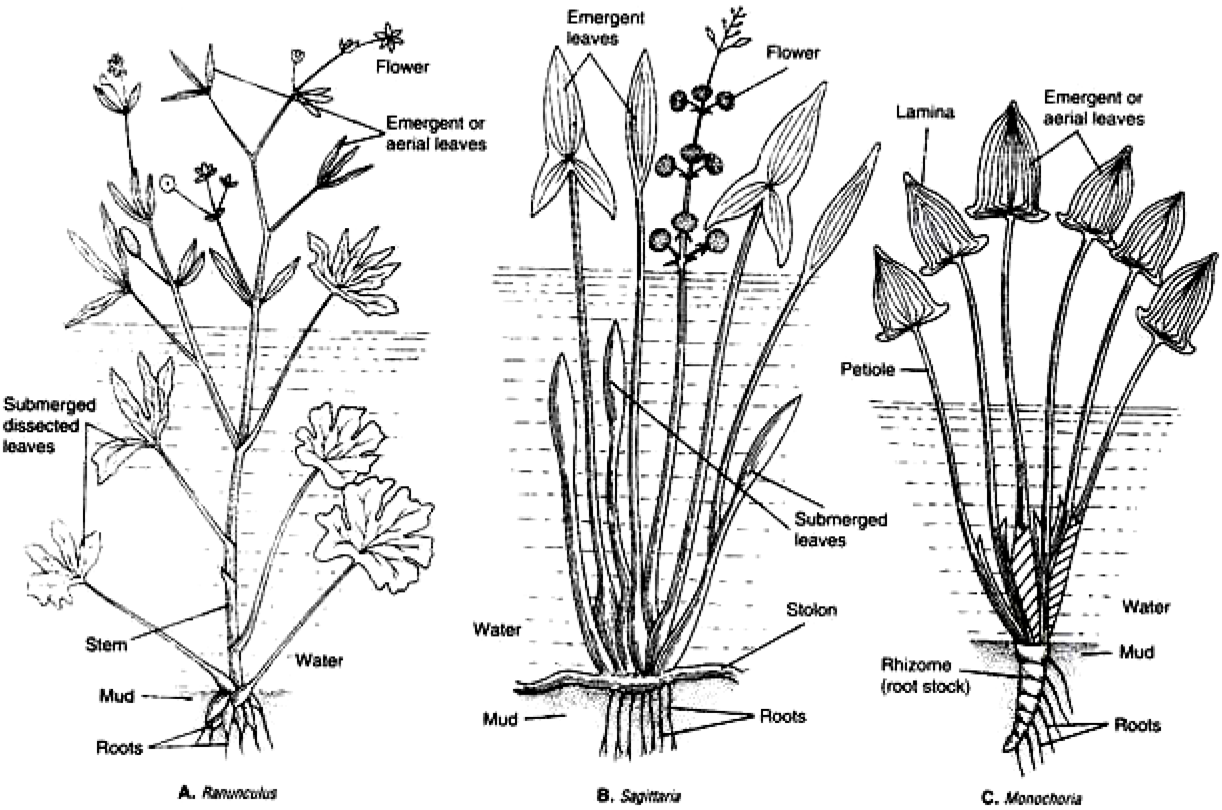

Fig. 8.3. Rooted emergent hydrophytes with heterophylly

(b) Floating hydrophytes:

Plants that float on the surface or slightly below the surface of water are called floating hydrophytes. These plants are in contact with both water and air. They may or may not be rooted in the soil. On this ground, the floating plants have been divided into two groups.

(i) Free floating hydrophytes:

These plants float freely on the surface of water but are not rooted in the mud. Examples- *wolffia arhiza and Wolffia microscopica (a rootless minutes duck weed). Trapa bispinosa, Lymnanthemum. Eichhornia crassipes (water hyacmth, verna—Jalkumbhi), Salvinia (a fern), Azolla (a water fern) (Fig. 8.6).*

(ii) Floating but rooted hydrophytes:

Some submerged plants are rooted in muddy substrata of Ponds Rivers and lakes but their leaves and flowering shoots float on or above the surface of water. They are grouped as floating but rooted hydrophytes. *Nelumbium speciosum (Lotus), Victoria regia (*water *lily), Ceratopteris thalictroides (a hydrophytic fern of family Parkariaceae),* etc. (Fig. 8.5).

(c) Amphibious hydrophytes:

These plants are adapted to both aquatic and terrestrial modes of life. Amphibious plants grow either in shallow water or on the muddy substratum^ Amphibious plants which grow in saline marshy places are termed as ‘halophytes. Roots and some parts of stems and leaves in these plants may be submerged in water or buried m mud but some foliage, branches and flowering shoots spring well above the surface of water or they may spread over the land (Fig. 8.3).

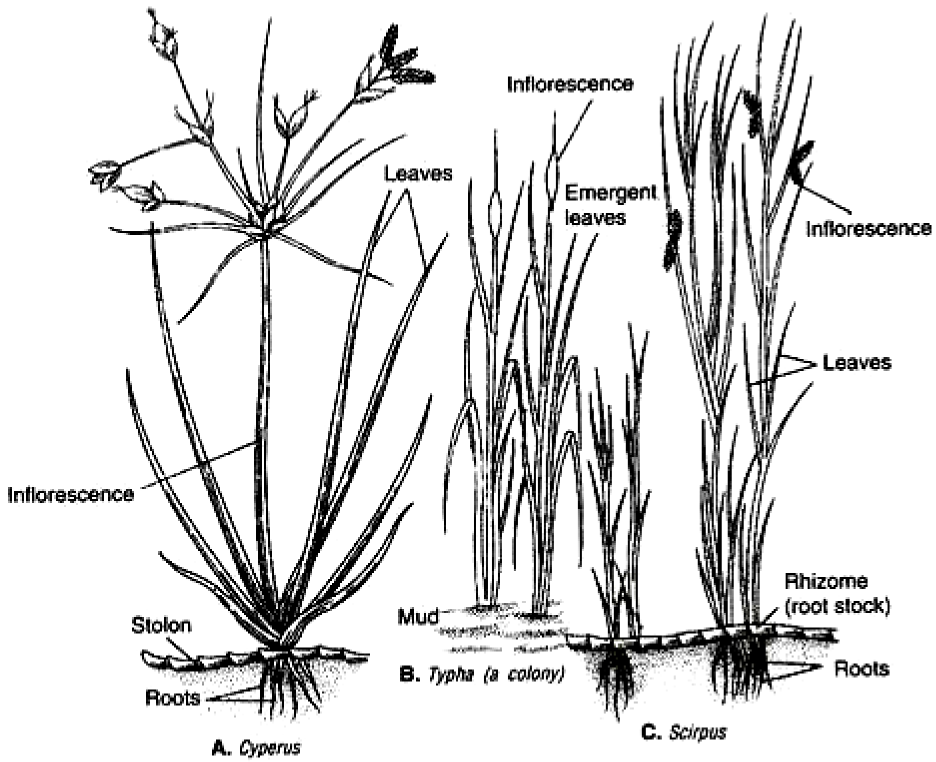

Fig. 8.4. Marsh plants.

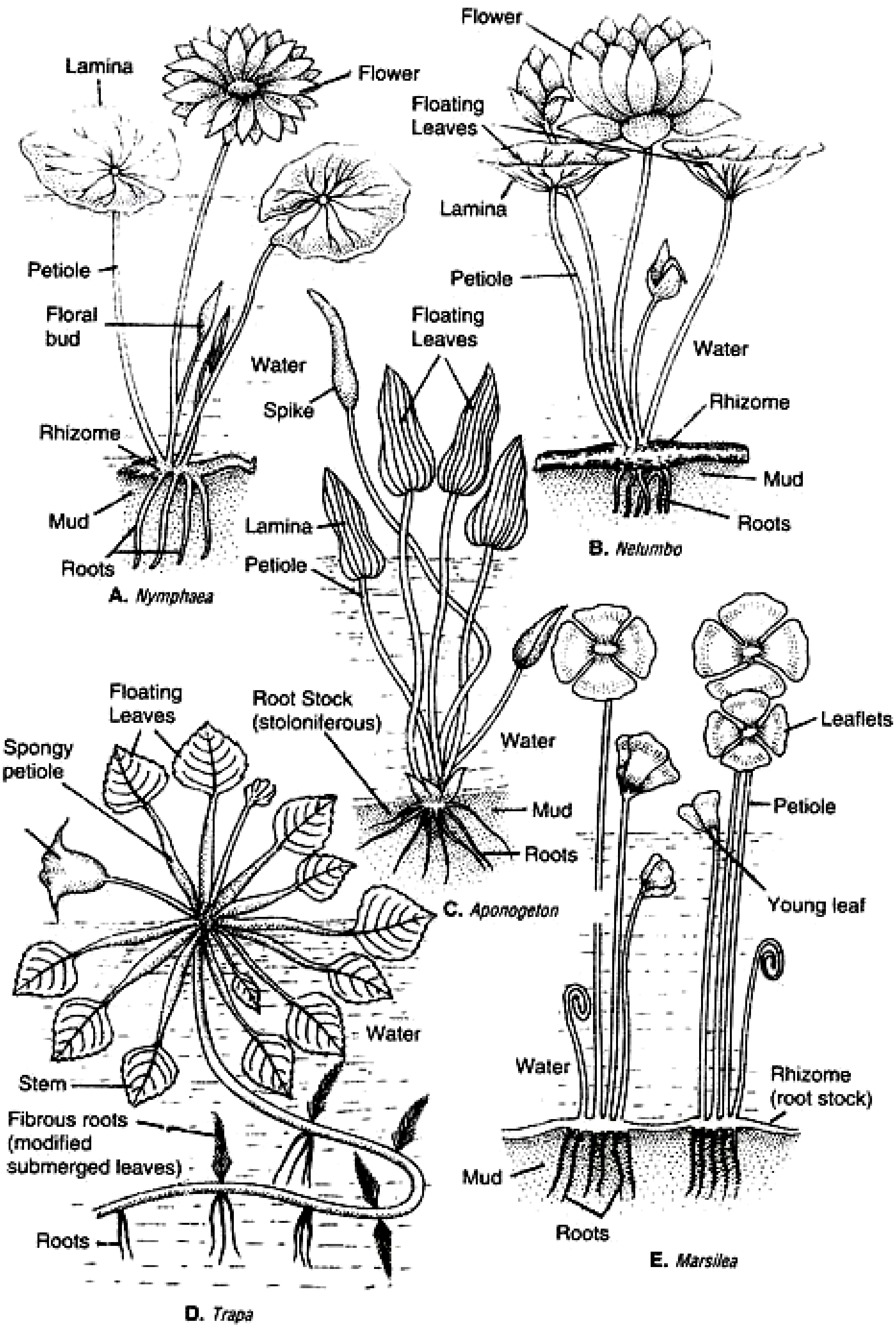

Fig. 8.5. Rooted hydrophytes with floating leaves.

These are listed below:

1. Temperature of water

2. Osmotic concentration of water

3. Toxicity of water

The osmotic concentration and toxicity are dependent upon the amount and nature of chemical substances dissolved in water. The physiology of aquatic plants is greatly affected by the change in osmotic concentration of water. The aquatic plants are subjected to less extremes of temperature because water is bad conductor of heat (i.e., it takes long time m its heating and cooling). Hydrophytes are less affected as the transpiration from the plant tissue is completely out of question.

Hydrophytic Adaptations:
As the aquatic environment is uniform throughout, the hydrophytes develop very few adaptive features.

Important features of these plants are described in the following heads:
A. Morphological:
(i) Roots:
Root systems in hydrophytes are poorly developed which may or may not be branched in submerged hydrophytes. Roots are meaningless as body which is in direct contact with water acts as absorptive surface and absorbs water and minerals. This may probably be the reason why roots in hydrophytes are reduced or absent. Roots of floating hydrophytes show very poor development of root hairs.

Roots in floating plants do not possess true root caps but very often they develop root pockets or root sheaths which protect their tips from injuries (Fig. 8.5). Exact functions of these root pockets, however, are not fully understood. Some rooted hydrophytes like Hydrilla (Fig. 8.6), Valhsnena sptrahs, Elodta canadensis, though they derive their nourishments from water by their body surfaces, are partly dependent on their roots for minerals from the soil.

Roots are totally absent in some plants, e g., Ceratophyllum, Salvinia, Azolla, Utricularia, etc. In Jussiaea repens two types of roots develop when the plants grow on the surface of water, some of them are floating roots which are negatively geotropic having spongy structures (Fig. 8.7). The floating roots keep the plants afloat.

(ii) Stem:
In aquatic plants, stem is very delicate and green or yellow in colour (Fig. 8.2 A, B). In some cases it may be modified into rhizome or runner, etc. (Fig. 8.2 D, 8.4).

(iii) Leaves:
(a) In floating plants leaves are generally peltate, long, circular, light or dark green in colour, thin and very smooth. Their upper surfaces are exposed in the air but lower Les are generally

in touch with water. In lotus plant petioles of leaves show indefinite power of growth and they keep the laminae of leaves always on the surface of water.

(b) Heterophylly:

Some aquatic plants develop two different types of leaves in them. This phenomenon is termed as heterophylly. Examples are Sagittaria sagittaefolia, Ranunculus aquatilis, Limnophila heterophylla, Salvinia, Azolla etc. In this phenomenon, generally the submerged leaves are linear ribbon shaped or highly dissected and the leaves that are found floating on or above the surface of water are broad circular or slightly lobed (Fig. 8.3 A, B, C). The occurrence heterophylly is associated probably with the following characteristic physiological behaviours of these aquatic plants.

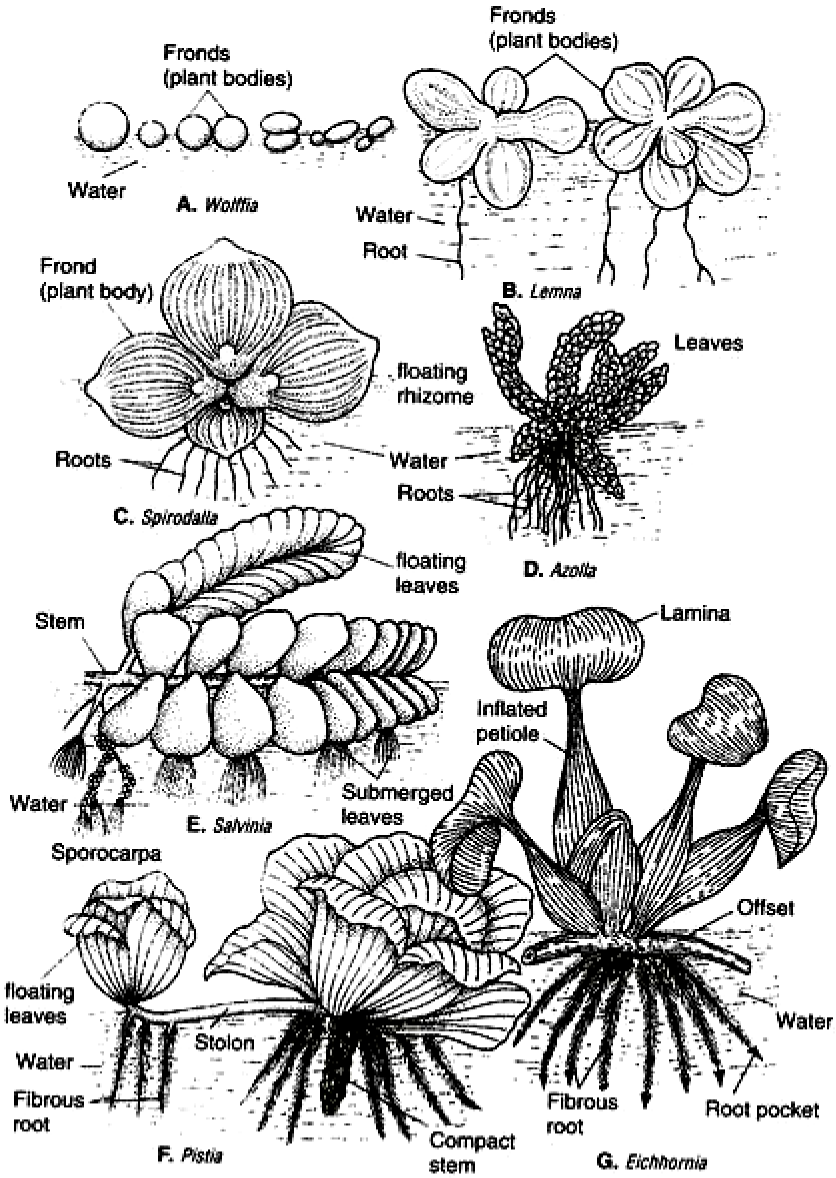

Fig. 8.6. Free floating hydrophytes.

1. Quantitative reduction in transpiration.

2. The broad leaves on the surface overshadow the submerged dissected leaves of the same plant and thus they reduce the intensity of light falling on the submerged leaves. The submerged leaves require light of very low intensity.

3. Plants show very little response to drought because the necessity of excess water during drought period is compensated by submerged leaves which act as water absorbing organs.

4. Variation in the life-forms and habitats.

5. Broad leaves found on the surface of water transpire actively and regulate the hydrostatic pressure in the plant body.

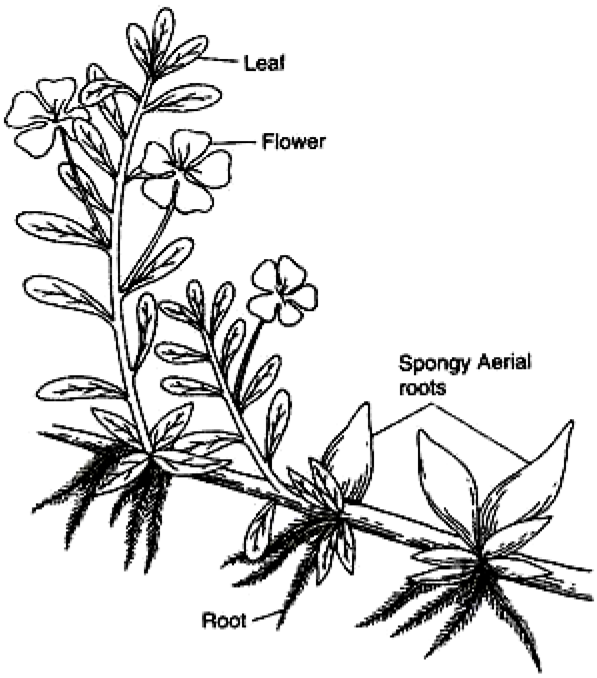

Fig. 8.7. *Jussiaea repens* showing spongy respiratory roots.

(c) Leaves of free floating hydrophytes are smooth, shining and frequently coated with wax. The wax coating protects the leaves from chemical and physical injuries and also prevents the water clogging of stomata.

(d) In floating plants of water hyacinth, Trapa etc., the petioles become characteristically swollen and develop spongyness which provides buoyancy to these plants (Fig. 8.6).

(e) Leaves in submerged hydrophytes are generally small and narrow. In some case, e.g., Myriophyllum, Utricularia, Ceratophyllum, etc., they may be finely dissected (Fig. 8.2). The mall slender terete segments of dissected leaves offer little resistance against the water currents. In this way plants are subjected to little mechanical stress and strain of water.

(f) In the Amphibious plants, the leaves that are exposed to air show typical mesophytic features. They are more tough than the leaves of other groups of hydrophytes.

(g) Pollination and dispersal of fruits and seeds are accomplished by the agency of water. Seeds and fruits are light in weight and thus they can easily float on the surface of water.

(h) Vegetative reproduction is common method of propagation in hydrophytes. It is accomplished either through fragmentation of ordinary shoots or by winter buds. In algae, reproduction is accomplished by zoospores and other specialized motile or non-motile spores.

B. Anatomical Modifications:
The anatomical modifications in hydrophytes aim mainly at:
1. Reduction in protecting structures,

2. Increase in the aeration,

3. Reduction of supporting or mechanical tissues, and

4. Reduction of vascular tissues.

Various anatomical adaptations of hydrophytes are listed below:

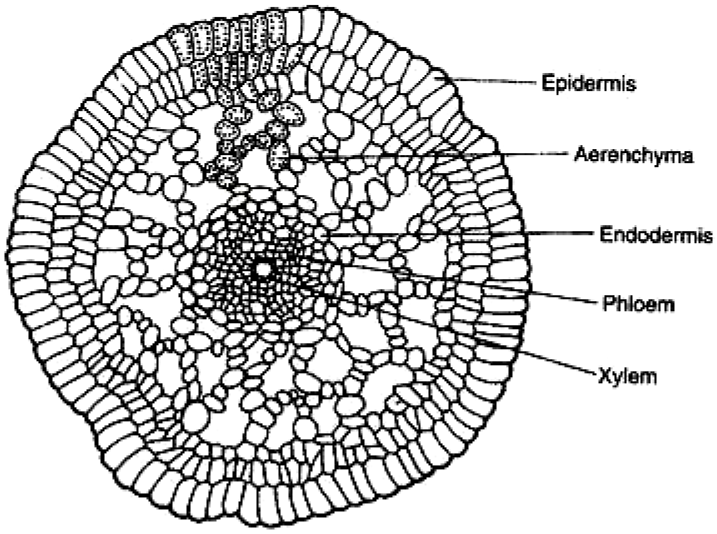

Fig. 8.8. T.S. of *Hydrilla* stem.

1. Reduction in protecting structures:
(a) Cuticle is totally absent in the submerged parts of the plants. It may be present in the form of very fine film on the surfaces of parts which exposed to atmosphere.

(b) Epidermis in hydrophytes is not a protecting layer but it absorbs water, minerals and gases directly from the aquatic environment. Extremely thin cellulose walls of epidermal cells facilitate the absorption process.

(c) Epidermal cells contain chloroplasts, thus they can function as photosynthetic tissue, especially where the leaves and stems are very thin, e.g. Hydrilla (Fig. 8.8).

(d) Hypodermis in hydrophytes is poorly developed. Its cells are extremely thin walled.

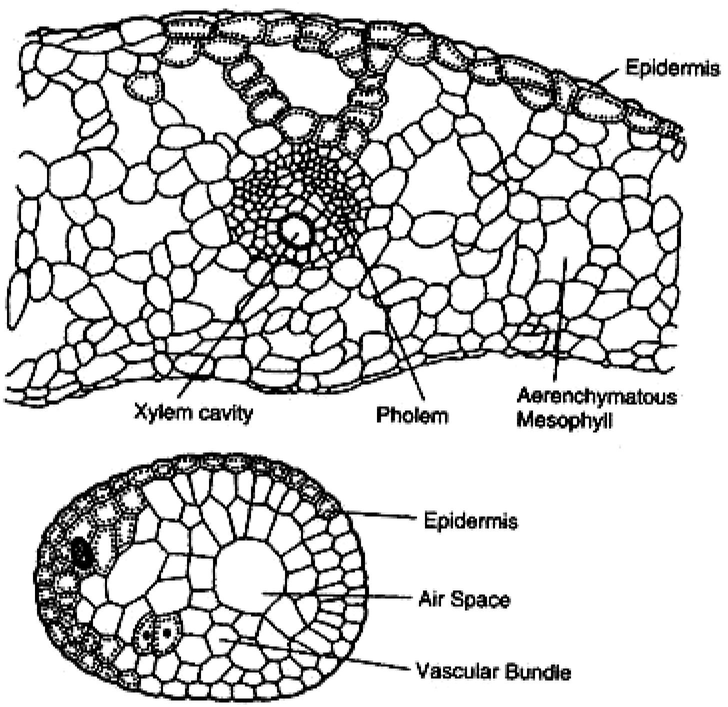

Fig. 8.9. A, B—T.S. of submerged leaves; *A. Vallisneria and B. Ceratophyllum.*

2. Increase in the aeration:

(a) Stomata are totally absent in submerged parts of the plants (Fig. 8.9, 8.10 C & D). In some exceptional cases, vestigial and functionless stomata have been noticed. In these cases exchange of gases takes place directly through cell walls. In the floating leaves, stomata develop in very limited number and are confined only to the upper surface (Fig. 8.10 A). In amphibious plants stomata may be scattered on all the aerial parts and they develop comparatively in larger number per unit area than those on the floating leaves (Fig. 8.11).

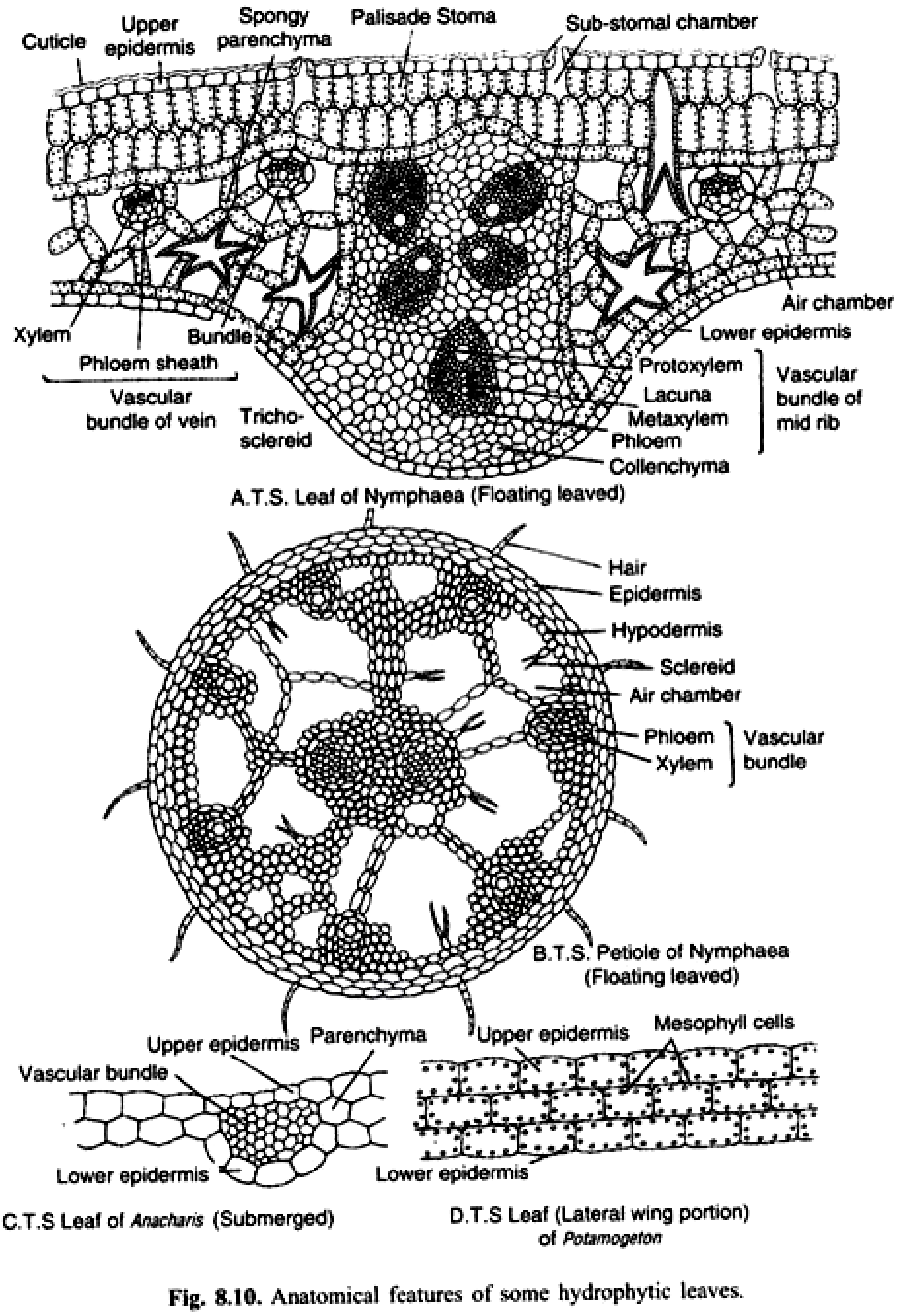

Fig. 8.10. Anatomical features of some hydrophytic leaves.

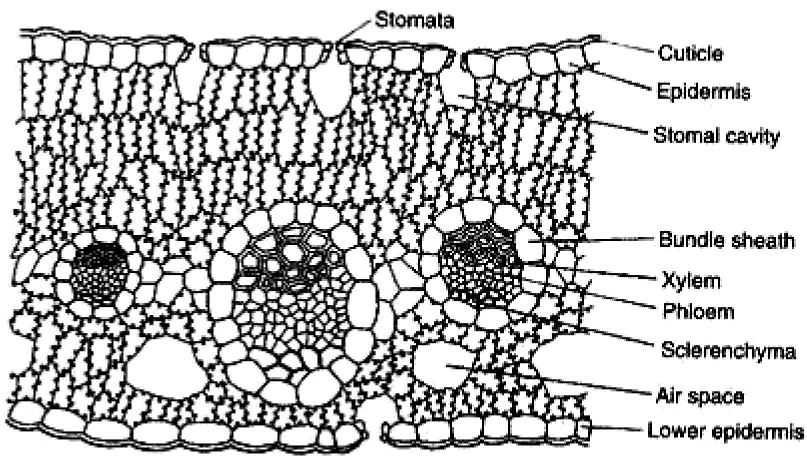

Fig. 8.11. V.S. of an amphibious leaf.

(b) Air chambers:

Aerenchyma in submerged leaves and stem is very much developed. Air chambers are filled with respiratory gases and moisture. These cavities are separated from one another by one or two cells thick chlorenchymatous partitions. The different types of air chambers are shown in Figs. 8.8, 8.9 A, and 8.10. CO_2 present in the air chambers is used in the photosynthesis and the O_2 produced in the process of photosynthesis and also that already present in the air chambers is used in respiration.

The air chambers also develop finely perforated cross septa which are called diaphragms (Fig. 8.12). The diaphragms afford better aeration and perhaps check floating. The Aerenchyma provides buoyancy and mechanical support to aquatic plants. Air chambers are abundantly found in the fruits of hydrophytes rendering them buoyant and thus facilitating their dispersal by water.

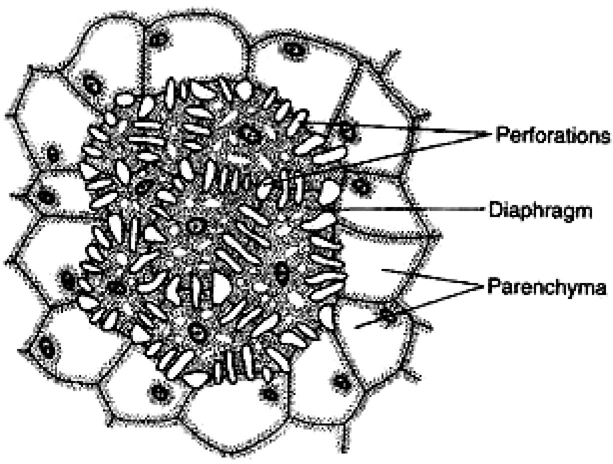

Fig. 8.12. Detailed structure of diaphragm of *Pontederia.*

Development of air chambers in the plants is governed by habitat. This point is clear from the anatomy of Jussiaea suffructicosa. In this case, air chambers develop normally if plants are growing in water but they seldom develop if the plants are growing on the land.

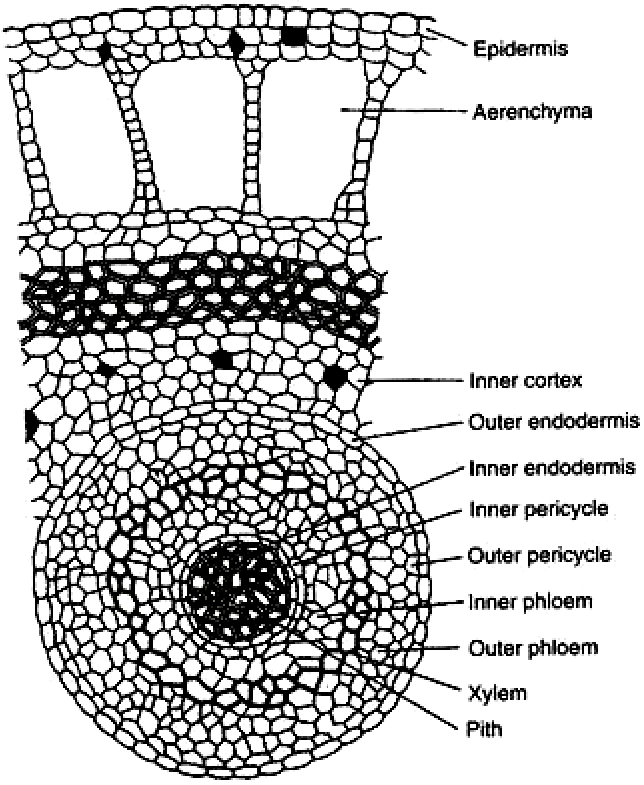

Fig. 8.13. T.S. of *Marsilea rhizome* (An amphibious hydrophyte).

3. Reduction of supporting or mechanical tissues:

(a) Mechanical tissues are absent or poorly developed in the floating and submerged parts of plants because buoyant nature of water saves them from physical injuries. The thick walled sclerenchymatous tissue is totally absent m submerged and floating hydrophytes. They may, however, develop in the cortex of amphibious plants particularly in the aerial or terrestrial parts (Figs. 8.13, 8.14 B, D). Generally elongated and loosely arranged spongy cells are found in the plant body. These thin-walled cells, when turgid, provide mechanical support to the plants (Figs. 8.15, 8.16 and 8.17).

(a) The reduction of absorbing tissue (roots act chiefly as anchors and root hairs are lacking).

(b) In water lily and some other plants, special type of star shaped lignified cells, called asterosclereids, develop which give mechanical support to the plants (Fig. 8.10 A, B).

4. Reduction of vascular tissues:

Conducting tissue is very poorly developed. As the absorption of water and nutrients takes place through the entire surface of submerged parts, there is little need of vascular tissues in these plants. In the vascular tissues, xylem shows greatest reduction. In some cases, it consists of only a few tracheids while in some, xylem elements are not at all developed (Fig.

8.18). Some aquatic plants, however, show a lacuna in the centre in the place of xylem. Such spaces resemble typical air chambers (Fig. 8.8).

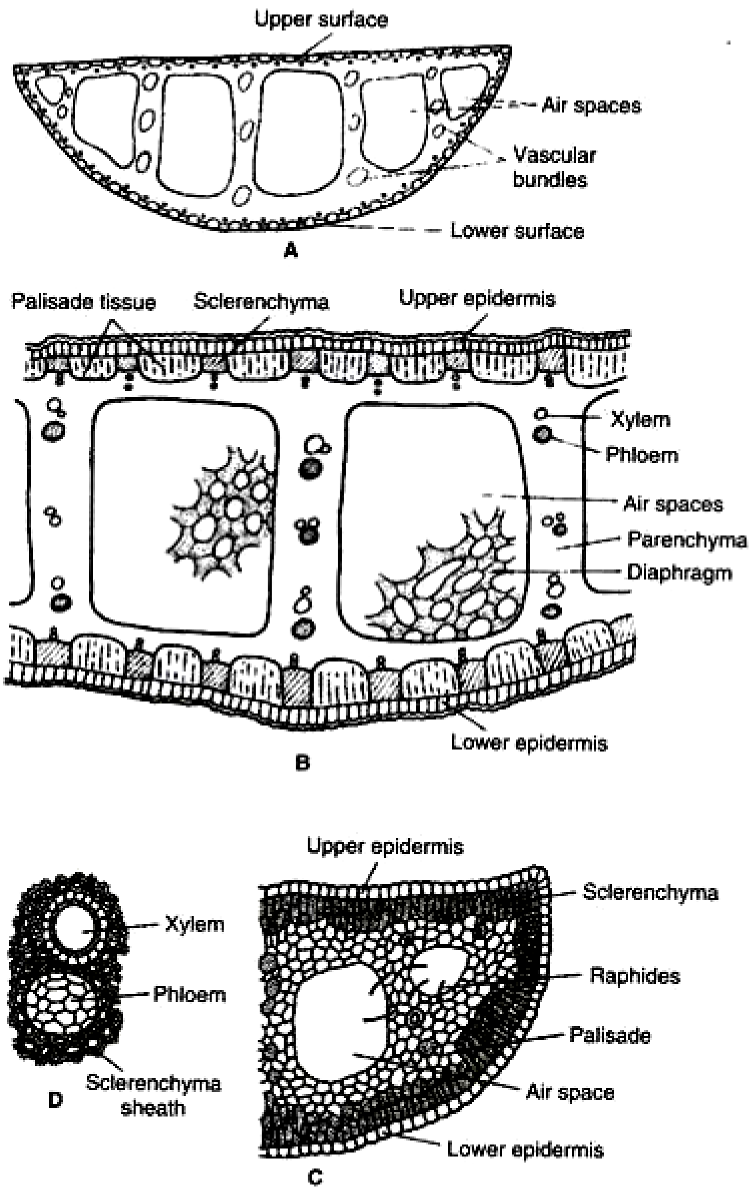

Fig. 8.14. Anatomy of leaf of *Typha*, a marshy hydrophyte. A : T.S. of leaf (diagrammatic), B : detail of a part of A; C, detail of corner of leaf, D : single vascular bundle.

Phloem tissue is also poorly defined in most of the aquatic plants but in some cases it may develop fairly well. Sieve tubes of aquatic plants are smaller than those of mesophytes. Phloem parenchyma is extensively developed. Endodermis may or may not be clearly defined. The Vascular bundles are generally aggregated towards the centre. Secondary growth in thickness does not take place in the aquatic stem and roots.

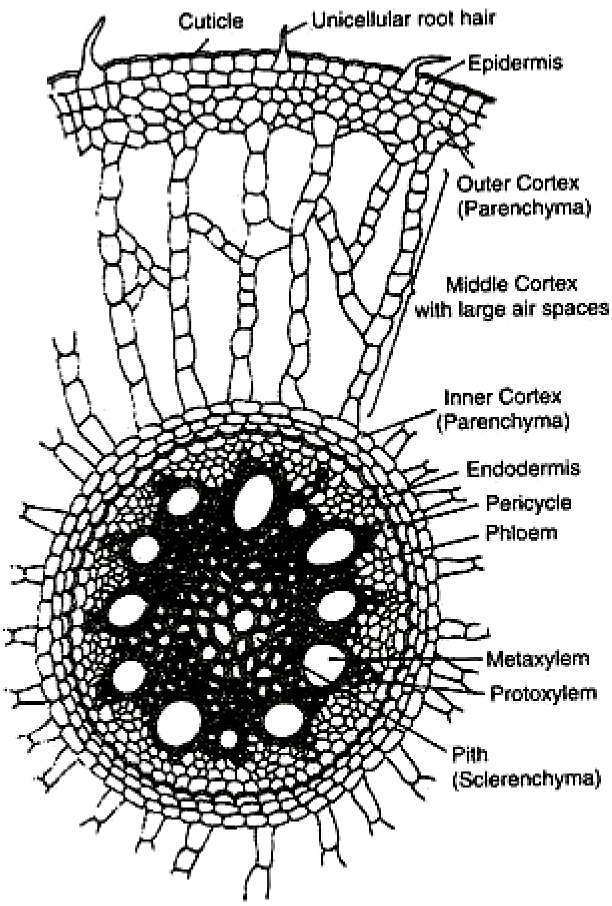

Fig. 8.15. T.S. of root of *Typha latifolia* (monocotyledonous) showing air spaces in cortical region and sclerenchymatous pith.

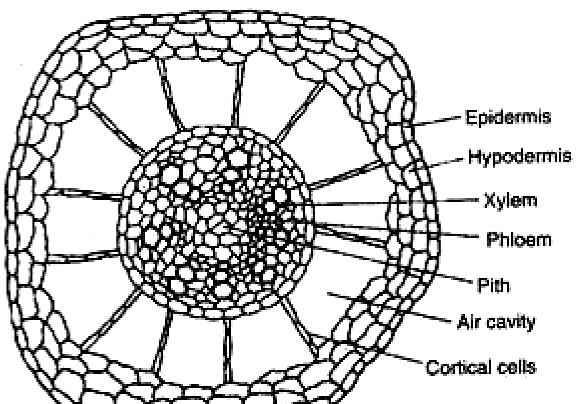

Fig. 8.16. T.S. of stem of *Jussiaea*.

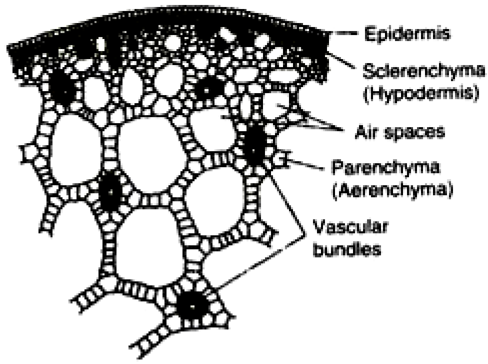

Fig. 8.17. T.S. of petiole of *Eichhornia.*

Distinctive features of different groups of hydrophytes are summarized in the following chart.

	Submerged plants 1		Floating plants 2		Amphibious plants 3
1.	Entire surface of plant body remains in direct contact with water.	1.	Some parts of the plants are in contact with water and some float on or above the surface of water.	1.	Some parts of the plant body grow in water while some others above the surface of water or even on the land.
2.	Leaves take CO_2 and oxygen form water.	2.	These plants take CO_2 and oxygen partly from air and partly from water.	2.	Generally the leaves absorb CO_2 and oxygen from the air because they are well exposed and the exchange of gases can take place very easily through stomata.
3.	Heterophylly is not so common.	3.	Heterophylly may develop in these plants.	3.	Heterophylly is very common.
4.	Leaves are greatly reduced in size. They may be ribbon shaped, thin and sometimes very finely dissected.	4.	Submerged leaves in the floating plants are thin, ribbon shaped, entire or dissected but those floating on the surface of water are well expanded and entire.	4.	Leaves are large, entire, tough and laminae or leaflets are found much above the surface of water.
5.	Cuticle, suberin and epidermal hairs are not at all developed. Epidermis acts as absorptive surface rather than a protecting layer. A thin layer of mucilage may be present on the surface.	5.	Surface of plant body is coated with a thin film of wax which protects the plant tissue from injurious effects of water and it also prevents clogging of stomata.	5.	Cuticle develops on the aerial parts of the plants.
6.	Stomata are absent or rarely present in very reduced state.	6.	Stomata are confined only to the upper surface of floating leaves.	6.	Stomata are confined to both upper and lower surfaces of the aerial leaves.
7.	Mesophyll tissue is in the form of aerenchyma enclosing large air chambers. Palisade and spongy parenchyma are not very well differentiated.	7.	Palisade cells are less developed and spongy tissue is aerenchyma.	7.	Mesophyll shows clear differentiation into spongy and palisade tissues. Spongy parenchyma is very well developed with large air passages and diaphragms.
8.	Stems are very slender and much reduced. They creep on the substratum either in the form of rhizomes or runners. The stem shows poorly developed vascular bundles. Aerenchyma is very well developed and air chambers are separated by cross septa or diaphragms.	8.	Stem is well developed and the fibrovascular system is very much reduced, aerenchyma develops in abundance and air chambers are quite large.	8.	Stem is extensively developed but in some, it may be reduced to rhizome. It shows clear differentiation of epidermis, cortex and stelar or vascular zones. Cortex in some cases is differentiated into distinct zones. Outer cortex is aerenchymatous enclosing a number of big air spaces. Inner cortex and pith may be formed of thick walled cells.
9.	Roots in submerged plants are greatly reduced, unbranched and without root hairs. They act simply as an anchorage organs. The root system shows poor internal organisation.	9.	In some, root is absent while in others, it may be fully developed. Root hairs in free floating plants lie at right angles to the axis of main root. Some roots may be modified into floats, e.g., in Jussiaea. Roots show poor differentiation of internal tissues. It functions as absorbing as well as anchorage organ.	9.	Roots in amphibious plants are well developed. They show proper differentiation of all internal tissues. Root hairs develop on the epidermis.

Xerophytes:
Plants which grow in dry habitats or xeric conditions are called xerophytes. Places where available water is not present adequate quantity are termed xeric habitats.

Xeric habitats may be of following types:
1. Habitats physically dry (where water retaining capacity of the soil is very low and the climate is dry, e.g., desert, rock surface, waste land, etc.).

2. Habitats physiologically dry (places where water is present in excess amount but it is not such as can be absorbed by the plants easily. Such habitats may be either too salty or too acidic, too hot or too cold).

3. Habitats dry physically as well as physiologically, e.g., slopes of mountains.

Xerophytes are characteristic plants of desert and semi-desert regions, yet they can grow in mesophytic conditions where available water is in sufficient quantity. These plants can withstand extreme dry conditions, low humidity and high temperature.

When growing under un-favourable conditions, these plants develop special structural and physiological characteristics which aim mainly at the following objectives:
(i) To absorb as much water as they can get from the surroundings;

(ii) To retain water in their organs for very long time;

(iii) To reduce the transpiration rate to minimum; and

(iv) To check high consumption of water

Xerophytes are categorized into several groups according to their drought resisting power. These groups are as follows:
1. Drought escaping plants:
These xerophytes are short-lived. During critical dry periods they survive m the form of seeds and fruits which have hard and resistant seed-coats and pericarps respectively. At the advent of favourable conditions (which are of very short duration), the seeds germinate into new small sized plants which complete their life cycles within a few week time. The seeds become mature before the dry condition approaches.

In this way, plants remain unaffected by extreme conditions. These are called ephemerals or drought evaders or drought escapers. These plants are very common in the semiarid zones where rainy season is of short duration. Examples—(Papilionatae), some inconspicuous compositae (e.g., Artemesid) and members of families Zygophyllaceae, Boraginaceae, some grasses etc.

2. Drought enduring plants:
These are small sized plants which have capacity to endure or tolerate drought.

3. Drought resistant plants:
These plants develop certain adaptive features in them through which they can resist extreme droughts. Xerophytes grow on a variety of habitats. Some grow on rocky soils (Lithophytes) some in deserts, some on the sand and gravels (Psammophytes) and some may grow on the waste lands (Eremophytes). Some plants of xeric habitat have water storing fishy organs, while some do not develop such structures.

On this ground xerophytes can be divided into two groups which are as follows:
(1) Succulent xerophytes.

(2) Non-succulents, also called true xerophytes.

Succulent xerophytes are those plants in which some organs become swollen and fleshy due to active accumulation of water in them or in other words, the bulk of the plant body is composed of water storing tissues. Water stored in these tissues is consumed during the period of extreme drought when the soil becomes depleted of available water.

Xerophytic Adaptations:
Plants growing in the dry habitats develop certain structural devices in them. These structure modifications in xerophytic plants may be of two types.

(i) Xeromorphic characters:
Xerophytic characters that are genetically fixed and inherited are referred to as xeromorphic. They will appear in the xerophytes irrespective of conditions whether they are growing in deserts or in humid regions. Halophytic mangroves and many other evergreen trees, although growing in moist conditions always develop xeromorphic characters.

(ii) Xeroplastic characters:
These features are induced by drought and are always associated with dry conditions. They are never inherited. These characters may disappear from plants if all the favourable conditions are made available to them.

Important xerophytic features are summarized under the following heads:
(1) Morphological (external) adaptations;

(2) Anatomical (internal) adaptations;

(3) Physiological adaptations.

1. External Morphology of Xerophytes:

(A) Roots:

Xerophytes have well developed root systems which may be profusely branched. It is extensive and more elaborate than shoot system. Many desert plants develop superficial root system where the supply of water is restricted to surface layer of the earth. The roots of perennial xerophytes grow very deep in the earth and reach the layers where water is available in plenty. Root hairs are densely developed near the growing tips of the rootlets. These enable the roots to absorb sufficient quantity of water.

(B) Stem:

Some of the important characteristics of xerophytic stems are listed below:

(i) Stems of some xerophytes become very hard and woody. It may be either aerial or subterranean.

(ii) They are covered with thick coating of wax and silica as in Equisetum. Some may be covered with dense hairs as is Calotropis.

(iii) In some xerophytes, stems may be modified into thorns, e.g., Duranta, Ulex, etc. (Fig. 8.19).

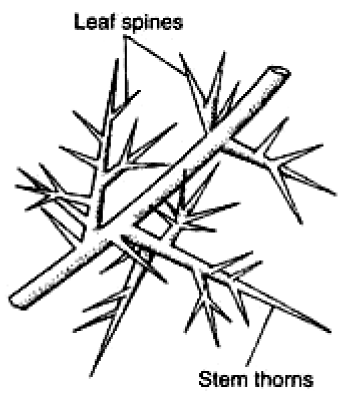

Fig. 8.19. Ulex Stem.

(iv) In stem succulents, main stem itself becomes bulbous and fleshy and it seems as if leaves in these plants are arising directly from the top of the roots. Example—Kleinia articulata.

(v) Stems in some extreme xerophytes are modified into leaf-like flattened, green and fleshy structures which are termed as phylloclades. Many cacti (Fig. 8.23A, B) and cocoloba (Muehlenbeckia) (Fig. 8.20 A) are familiar examples for this. In Ruscus plants, the branches developing in the axils of scaly leaves become metamorphosed into leaf-like structures, the phylloclades or cladophylls (Fig. 8.20 B).

In Asparagus plant (Fig. 8.20 C) also a number of axillary branches become modified into small needle-like green structures which look exactly like leaves. They are called cladodes. A number of species of Euphorbia also develop succulence and become green. In these plants, leaves are greatly reduced, so the main function of leaves, the photosynthesis, is taken up by these green phylloclades or cladodes which are modified stems.

(C) Leaves:

(i) In some xerophytes the leaves, if present, are greatly caducous, i.e., they fall early in the season, but in the majority of the plants leaves are generally reduced to scales, as in Casuarina (Fig. 8.21), Ruscus (Fig. 8.20 B), Asparagus (Fig. 8.20 C), etc.

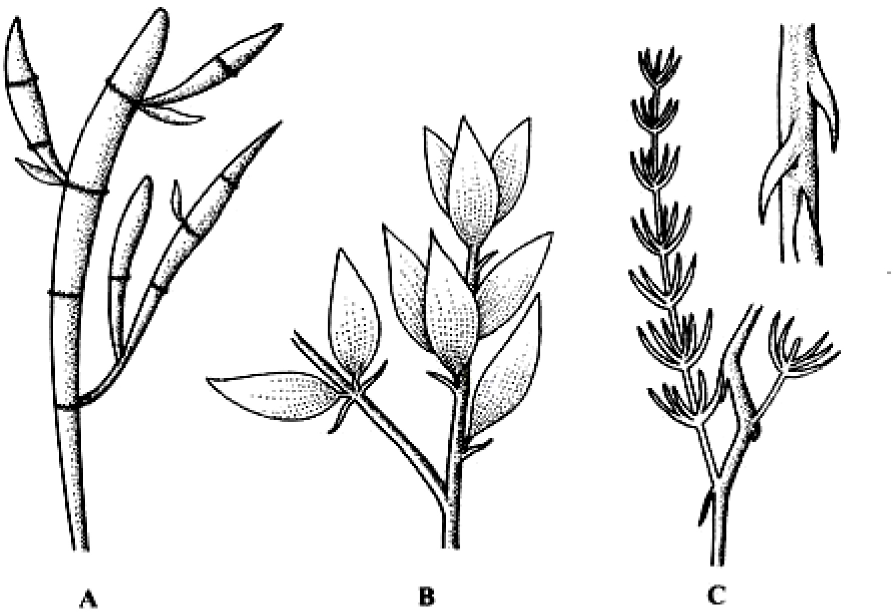

Fig. 8.20. A, B & C—Phylloclade and cladodes. A—Phylloclade of Cocoloba. B—Cladodes of *Ruscus*. C—Cladodes of *Asparagus*.

Fig. 8.21. *Casuarina.*

(ii) Some evergreen xerophytes have needle-shaped leaves, e.g., Pinus (Fig. 8.22 A, B).

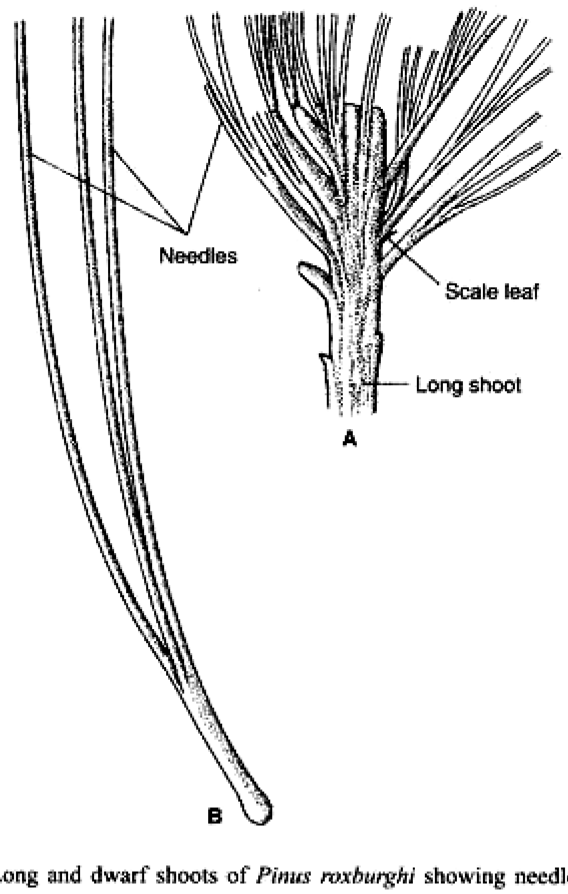

Fig. 8.22. A, B—Long and dwarf shoots of *Pinus roxburghi* showing needle-like leaves and scales.

(iii) In leaf succulents, the leaves swell remarkably and become very fleshy owing to storage of excess amount of water and latex in them. Plants with succulent leaves generally develop very reduced stems. Examples of leaf succulents are Sedum acre, Aloe spinossissima

(Gheekwar) (Fig. 8.23 C), Mesembryanthemum, Kleinia ficoides and several members of family Chaenopodiaceae.

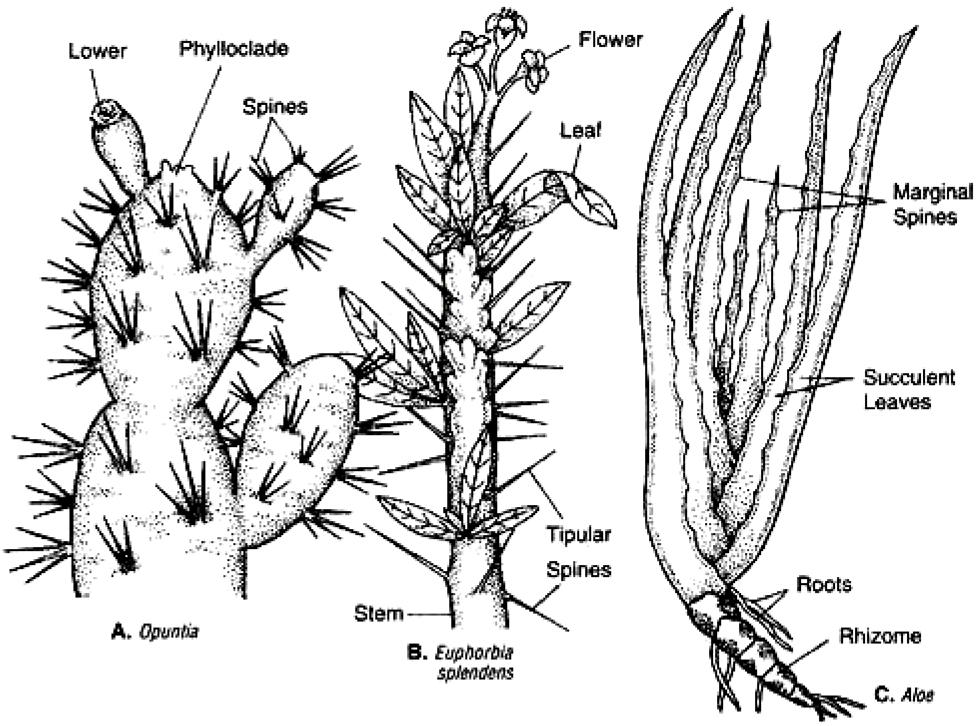

Fig. 8.23 Some succulent xerophytes.

(iv) In majority of xerophytes, leaves are generally much reduced and are provided with thick cuticle and dense coating of wax or silica. Sometimes they may be reduced to spines, as for example, in Ulex, Opuntia, Euphorbia splendens (Fig. 8.23 A, B), Capparis (Fig. 8.24 B) and Acacia (Fig. 8.24D).

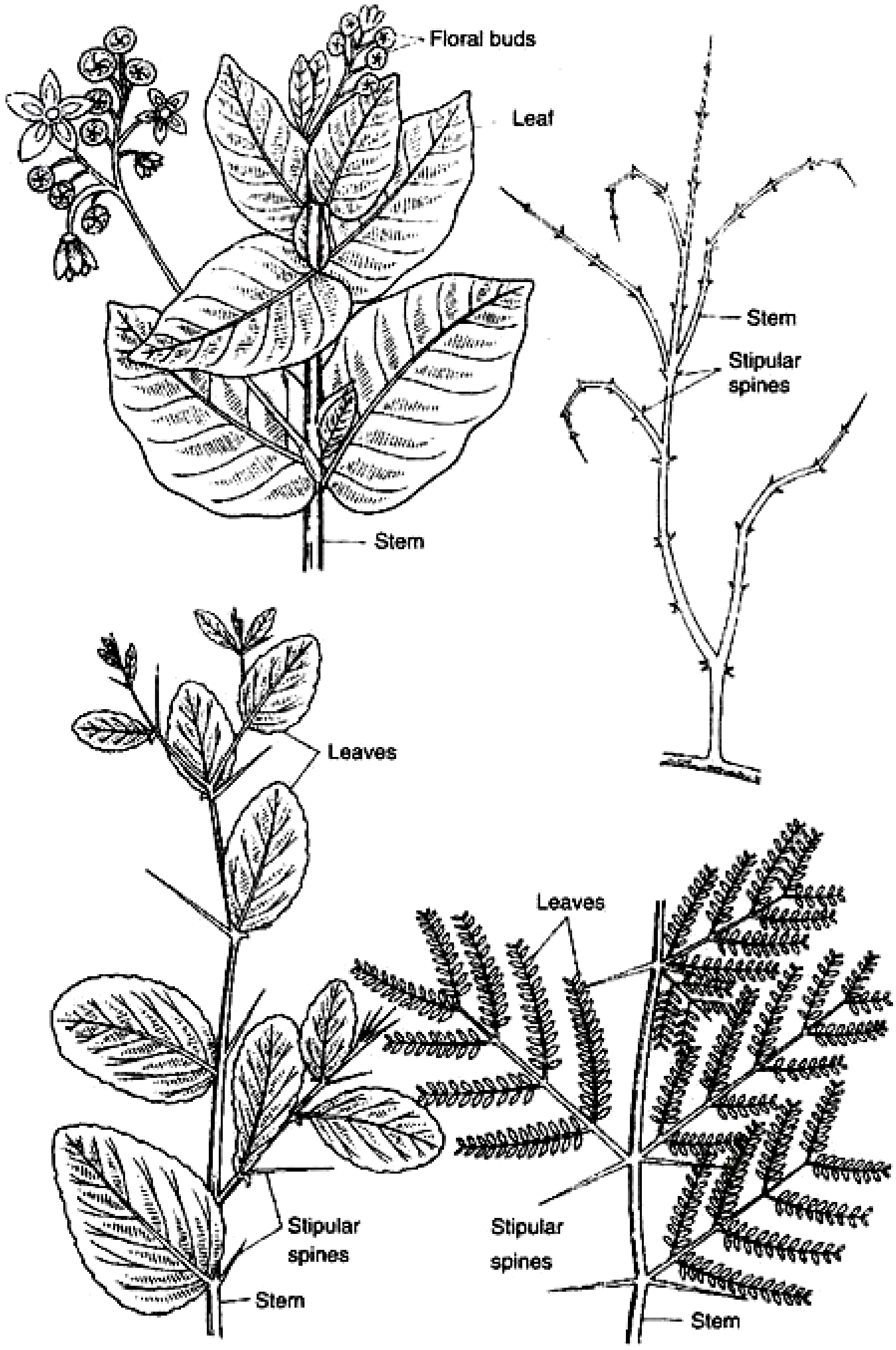

Fig. 8.24. Some common true xerophytes.

(v) Generally, the leaves of xerophytic species possess reduced leaf blades or pinnae and have very dense network of veins. In Australian species of Acacia (Babool) the pinnae are shed from the rachis and the green petiole swells and becomes flattened taking the shape of leaf. This modified petiole is termed as phyllode (Fig. 8.25). The phyllode greatly reduces the water loss, stores excess amount of water and performs photosynthesis.

(vi) Trichophylly. In some xerophytes especially those growing well exposed to strong wind, the under surfaces of the leaves are covered with thick hairs which protect the stomatal guard cells and also check the transpiration. Those xerophytes which have hairy covering on the leaves and stems are known as trichophyllous plants. Zizyphus (Fig. 8.24 C), Nerium, Calotropis procera (Fig. 8.24 A) are important examples.

(vii) Rolling of leaves. Leaves in some extreme xerophytic grasses have capacity for rolling or folding. In these cases stomata are scattered only on the upper or ventral surface and as the leaves roll upwardly, stomata are effectively shut away from the outside atmosphere. This is effective modification in these plants for reducing the water loss. Sun-dune grass is an important example for this (Fig. 8.27).

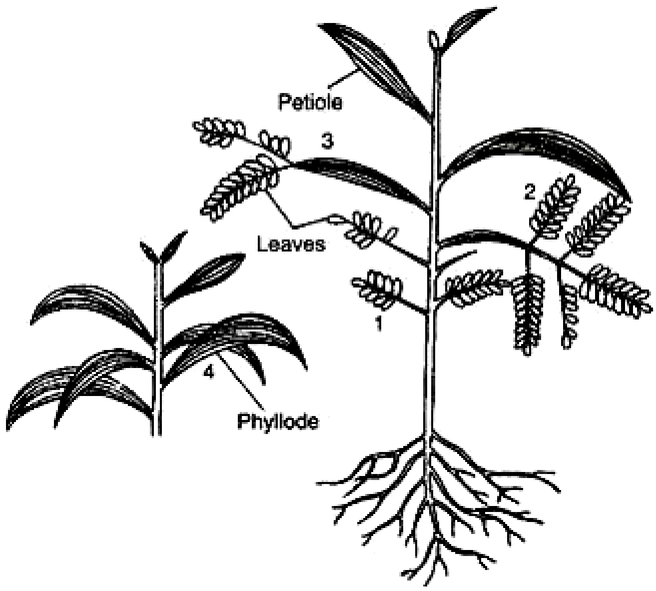

Fig. 8.25. *Acacia* phyllode. Figs. 1, 2, 3 and 4 show the gradual loss of pinnae and development of phyllodes.

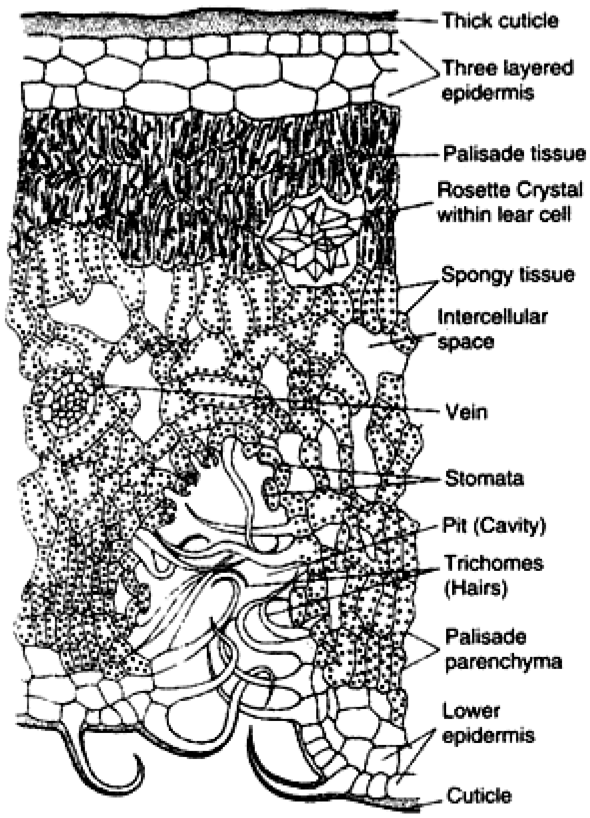

Fig. 8.26. T.S. of *Nerium* leaf lamina showing multilayered epidermis, compact mesophyll and hairy stomatal pit.

(D) Flowers, fruits and seeds. Flowers usually develop in the favourable conditions. Fruits and seeds are protected by very hard shells or coatings.

2. Anatomical Modifications in the Xeropliytes:

A number of modifications develop internally in the xeric plants and all aim principally at water economy.

The following are the anatomical peculiarities met within xerophytes:

(i) Heavy:

Heavy cutinisation, lignification's and wax deposition on the surface of epidermis (Fig. 8.26) and even in the hypodermis are very common in xerophytes. Some plants secrete wax in small quantity but some are regular source of commercial wax. Shining smooth surface of cuticle reflects the rays of light and does not allow them to go deep into the plant tissues. Thus, it checks the heavy loss of water.

(ii) Epidermis:

Cells are small and compact. It is single layered, but multiple epidermis is not uncommon. In Nerium leaf, epidermis is two or three layered (Fig. 8.26). In stems, the epidermal cells are radially elongated. Wax, tannin, resin, cellulose, etc., deposited on the surface of epidermis form screen against high intensity of light. This further reduces the evaporation of water from the surface of plant body. Certain grasses with rolling leaves have specialized epidermis (Figs. 8.27, 8.28).

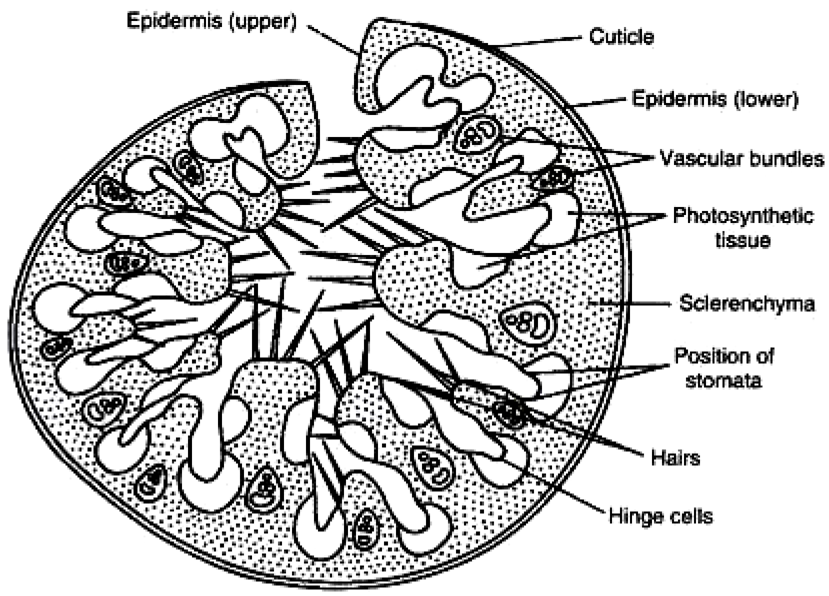

Fig. 8.27. Structure of xerophytic leaf. T.S. (diagrammatic) of *Ammophila arenaria* leaf showing protected stomata.

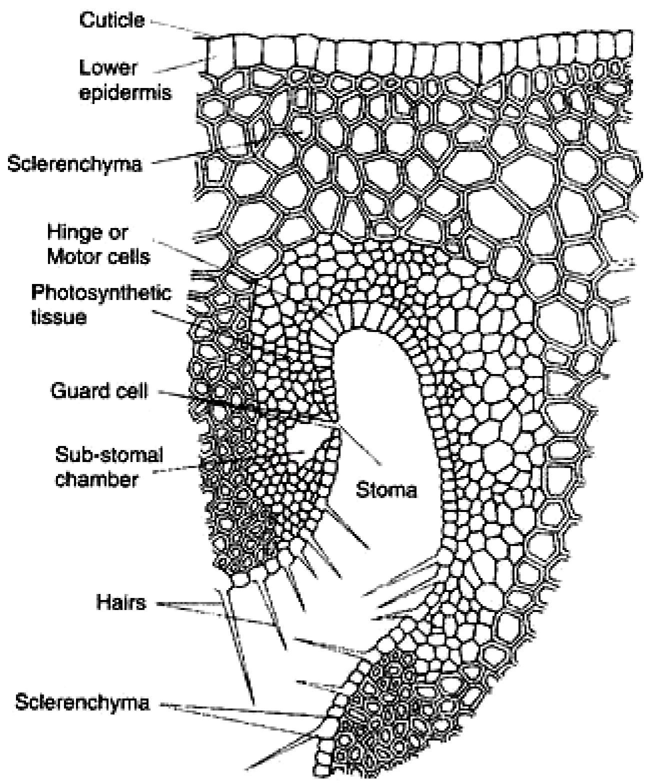

Fig. 8.28. Structure of xerophytic leaf. Part of T.S. of leaf of *Ammophila arenaria* between two ridges (detail).

In these, some of the epidermal cells that are found in the depressions become more enlarged than those found in the ridges. These enlarged cells are thin walled and are called bulliform cells or motor cells or hinge cells. These are found usually on the upper surface of leaves between two parallel running vascular bundles.

The highly specialized motor cells facilitate the rolling of leaves by becoming flaccid during dry periods. In moist conditions these cells regain their normal turgidity which causes unrolling of the leaf margins. Bulliform cells are of common occurrence in the leaf epidermis of sugarcane, bamboo, Typha and a number of other grasses.

(iii) Hairs:
Hairs are epidermal in origin. They may be simple or compound, uni- or multicellular. Compound hairs are branched at the nodes. These hairs protect the stomata and prevent excessive water loss. In some plants, surfaces of stems and leaves develop characteristic ridges and furrows or pits. The furrows and pits in these plants are the common sites of stomata. Hairs found in these depressions protect the stomata from the direct strokes of strong wind (Figs. 8.29, 8.30).

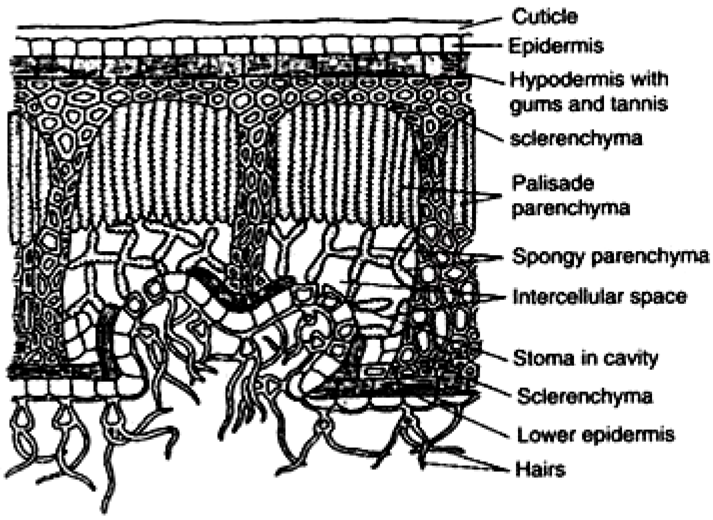

Fig. 8.29. Anatomy of xerophytic leaf. T.S. of *Banksia* leaf (sclerophyllous type).

(iv) Stomata:
In xerophytes, reduction of transpiration is of utmost importance. It is possible only if the stomatal number per unit area is reduced or if the stomata are elaborately modified in their structures. In xerophytes, number of stomata per unit area of leaf is greater than in mesophytes. They are generally of sunken type. In some cases, they may be found in the furrows or pits.

Subsidiary cells of sunken stoma may be of such shapes and arrangement that they form an outer chamber that is connected by narrow opening or the stoma. Such type of specialized stomata are very common in conifers, Cycas, Equisetum, etc. (Fig. 8.31). Walls of the guard cells and subsidiary cells are heavily cutinized and lignified in many xeric plants.

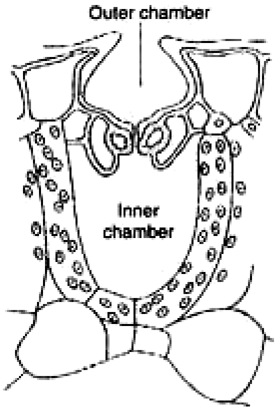

Fig. 8.31. A magnified sunken stoma.

These devices have little value in directly reducing transpiration when stomata are open. When the plants are wilting and stomata are closed then only lignified or cuticularized walls of guard cells have protecting properties and under such circumstances only cuticular transpiration is possible which is of little significance.

In dorsiventral leaves stomata are generally found on the lower surface, but m rolling leaves they are scattered mostly on the upper surface. In the rolled leaves, stomata are protected from the direct contact of outside wind. This is very important rather secured device for lowering the rate of transpiration in xerophytic grasses.

(v) Hypodermis:

In xerophytes, just below the epidermis, one or several layers of thick walled compactly grouped cells may develop that form the hypodermis. The cells may be much like those of epidermis and may either be derived from epidermis or from the cortex (m case of stem) or from the mesophyll (in case of leaf). The hypodermal cells may sometimes be filled with tannin and mucilage.

(vi) Ground tissue:

(a) In the stem, a great part of body is formed of sclerenchyma. In those cases, where the leaves are either greatly reduced or they fall in the early season, the photosynthetic activity is taken up by outer chlorenchymatous cortex (Fig. 8.32). The chlorenchymatous tissue is connected with the outside atmosphere through stomata. The gaseous exchange takes place in regular manner in the green part of stem.

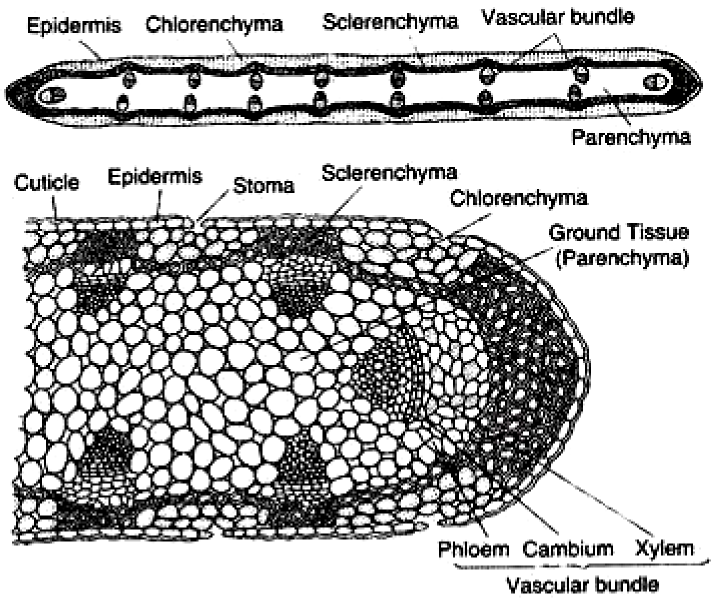

Fig. 8.35. *Homalocladium platycladum* (*Muehlenbeckia platycladus*) phylloclade (dicot); A—transection of phylloclade (diagrammatic); B—transection of phylloclade showing detail structure. The stomata, the cambium, the vascular bundles, the sclerenchyma and the chlorophyllous cells are clearly visible.

(vii) Conducting tissues: Conducting tissues, i.e., xylem and phloem, develop very well in the xerophytic body.

(2) Another experimented fact in the physiology of succulent plants is that their stomata open during night hours and remain closed during the day. This unusual feature is associated with metabolic activity of these plants. In dark, these plants respire and produce acids. The heavy accumulation of acids in the guard cells increases osmotic concentration which, m turn, causes inward flow of water in the guard cells. When guard cells become turgid the stomata open. In the sunlight, acids dissociate to produce carbon dioxide which is used up in the photosynthesis and as a result of this osmotic concentration of cell sap decreases which ultimately causes closure of stomata.

(3) In xerophytes, the chemical compounds of cell sap are actively converted into wall forming compounds that are finally incorporated into the cell walls. Conversions of polysaccharides into anhydrous forms as cellulose, formation of suberin, etc., are some examples.

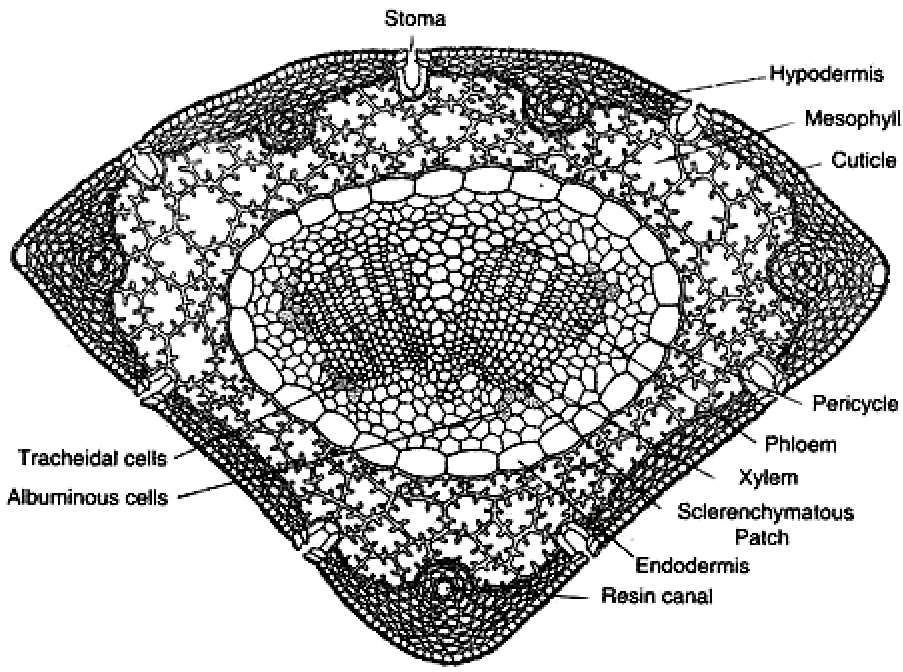

Fig. 8.36. T.S. of *Pinus* needle.

(4) Some enzymes, such as catalases, peroxidases, are more active in xerophytes than in mesophytes. In xerophytes, amylase enzyme hydrolyses the starch very actively.

(5) The capacity of xerophytes to survive during period of drought lies not only in the structural features but also in the resistance of the hardened protoplasm to heat and desiccation.

(6) Regulation of transpiration. Presence of the cuticle, polished surface, compact cells and sunken stomata protected by stomatal hairs regulate the transpiration.

(7) High osmotic pressure of cell sap. The xerophytes have very high osmotic pressure which increases the turgidity. The turgidity of cell sap exerts tension force on the cell walls. In this way, wilting of cell is prevented. High osmotic pressure of cell sap also affects the absorption of water.

PHYTOGEOGRAPHYCAL REGIONS OF INDIA

Vegetation of any place is modified by the environmental factors; climate, geology and biotic factors.

The great area of Indian subcontinent has wide range of climate and corresponding diversity in the vegetation.

India has been divided into the following botanical zones by D. Chatterjee (1962) Fig. 11.4:

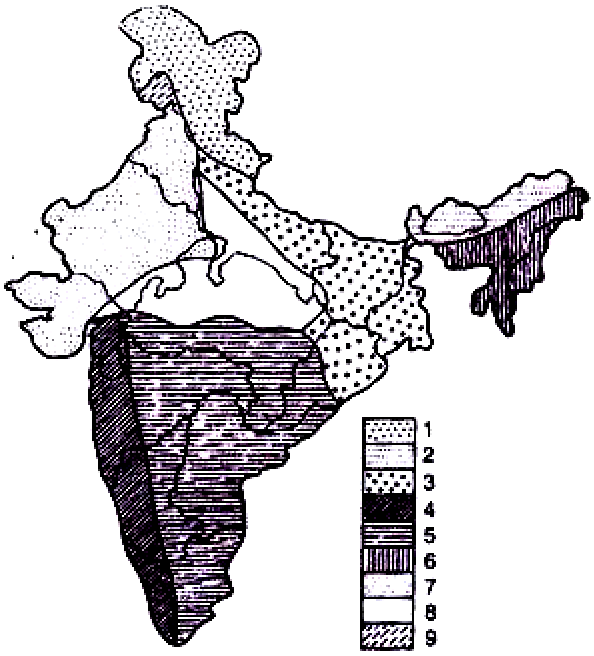

Fig. 11.4. Botanical zones of India.

(1) Western Himalayas,

(2) Eastern Himalayas,

(3) Indus plain,

(4) Gangetic plain,

(5) Central India,

(6) Deccan,

(7) Western coasts of Malabar,

(8) Assam, and

(9) Bay Islands of Andaman and Nicobar.

1. Western Himalayas:
The northern part of our country is bounded by highest ranges of Himalayas and is one of the important botanical regions of the world with climate and vegetation ranging from truly tropical near the low altitudes to temperate arctic types at the high altitudes. The northern mountain division can phytogeographically be divided into western, central and eastern zones.

Western Himalayas consist of north Kashmir, south Kashmir, a part of Punjab, H.P., Garhwal and Kumaon. This zone is wet in outer southern ranges and slightly dry in inner northern zone. The average annual rainfall in this region is from 100 to 200 cm. Snowfall occurs in this region during winter season. The region may be divided into three subzones (Fig. 11.5).

(i) Submontane zone or lower region or tropical and subtropical belts (up to about 1500 metres altitude from the sea level).

(ii) Temperate zone (from 1500 metres to 3500 metres altitude),

(iii) Alpine zone (above 3500 metres and up to the line of perpetual snow).

(i) Submontane or lower region or tropical and subtropical belts:
It includes outer Himalayas, particularly region of Siwaliks and adjoining areas where annual average rainfall is over 100 cm. This zone ranges between 300 and 1500 metres above sea level. In this zone, forests dominated by timber trees of Shorea robusta are common. Other important tree species are Salmalia malabaricum, Butea monosperma. Acacia catachu and Zizyphus species.

In the swampy areas, Dalbergia sisso (Shisham), Ficus glomerata, Eugenia jambolana are of common occurrence. In west dry regions sal trees are replaced by xeric plants particularly Zizyphus, Carissa, Acacia, and thorny Euphorbias. At higher elevation, around 1000 to 1500 metre altitude, cheer (pine) forests are also found at certain places. The common species of pine are Pinus longifolia and Pinus roxburghii. Ground vegetation is scanty.

(ii) Temperate zone:
It commonly ranges at the altitudes from 1500 to 3500 metres above the sea level. Oaks are dominant along with Populus, Rhododendron, Betula and Pyrus. Pinus excelsa, Cedrus deodara, Picea, Abies, Cupressus and Taxus baccata are found in the heavy rainfall region (between 1600 and 1800 m). Herbs are also common in this region. Common herbs are Ranunculus hirtila, Polygonum, Pedicularia, Potentilla argyrophylla. Primula, Delphinium, Clematis, crucifers and many members of asteraceae.

In cultivated drylands of Punjab, wheat and barley are main crops. In Kashmir, Betula (birch), Salix (cane), Populus (poplar) are of common occurrence. Besides these, Quercus semicarpifolia, Q. dilatata, Aesculus indica (chestnut) and many conifers are commonly met within this region. In west Kashmir rice cultivation is common Sar or saffron (Crocus sativus), apples, peaches, walnut, almonds and other fruits are important economic plants of Kashmir region.

(iii) Alpine zone:
Above the altitude of 3500 metres and up to snowline (about 5000 m) is alpine zone. The vegetation consists of evergreen conifers and some low and broad leaved trees. The vegetation of this region is characterized by cushion habit, dwarf nature and gregarious habit. In lower alpine region, shrubby forests are common which may be (a) Birch—fir forest which is fairly dense and is mixed with evergreen shrubby Rhododendron at higher level and (b) Birch— Rhododendron forests in which silver fir, Betula, Rhododendron and Juniperus are common. In the upper alpine region, prominent herbaceous plants are the species of Primula, Polygonum, Gentiana, Cassiope, Meconopsis, Saxifraga, Potentilla, Geranium, Aster, Astragalus etc. which form alpine meadows. At about 5000 metre altitude and above snow perpetuates round the year and plant growth is almost nil. This altitude is called snow line or ice line.

Populations of Draba, Braya, Cortia, Leontopodium go on increasing with the increase in altitude. Species of Ephedra, Juniperus, Berberis are also found scattered. Poa, Stipa and Fectuca are common grasses of alpine zone.

2. Eastern Himalayas:

Eastern Himalayas extend from Sikkim to upper Assam, Darjeeling and NEFA. Vegetation of this region differs from that of western Himalayas. The chief differences are due to changed environmental factors as heavy monsoon rainfall, less snowfall and high temperature and humidity.

This region can also be divided into:
(i) Tropical submontane zone

(ii) Temperate or Montane zone, and

(iii) Alpine zone (Fig. 11.5).

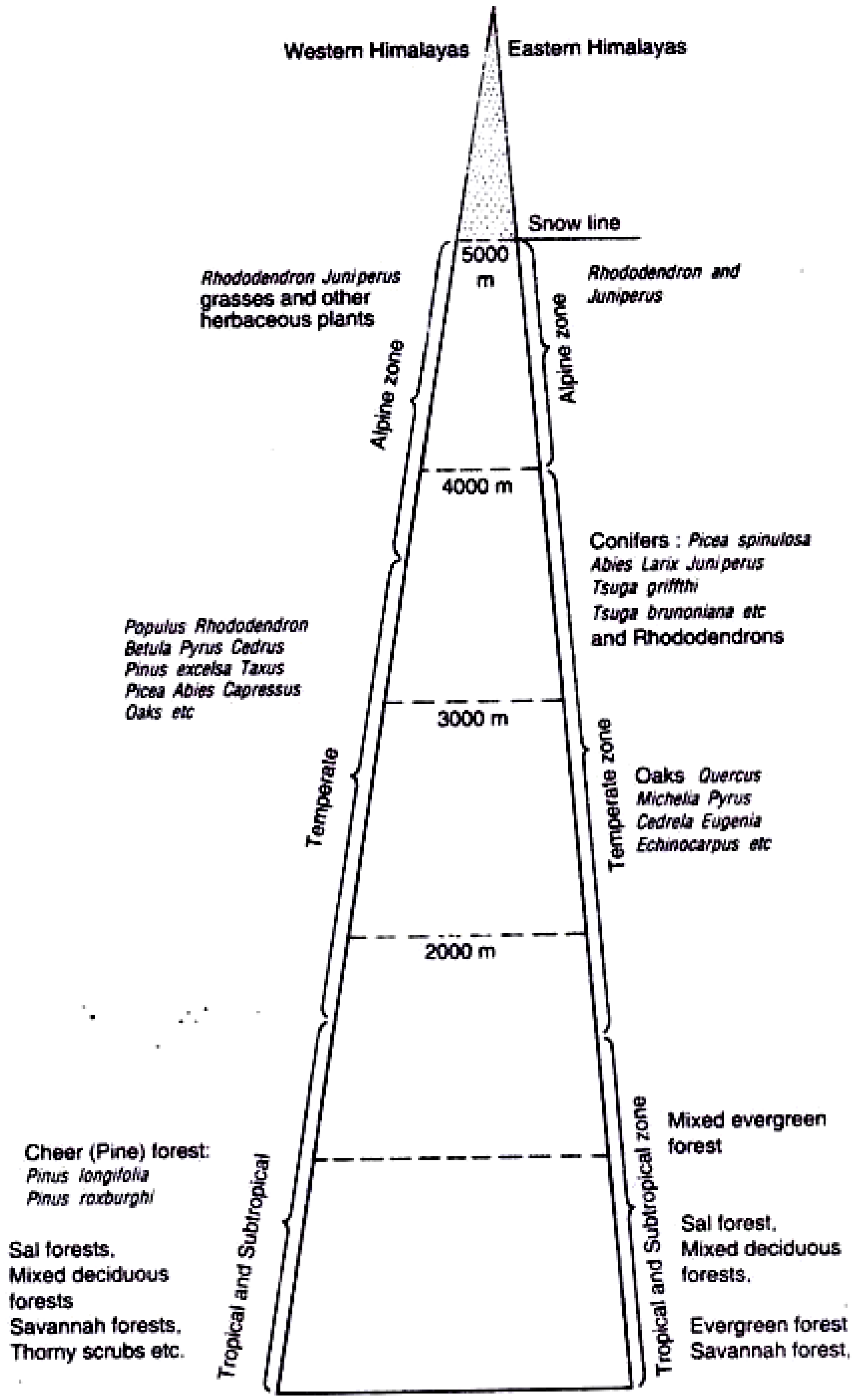

Fig. 11.5. Main types of vegetation at different altitudes in the Western and Eastern Himalayas.

(i) Tropical or Submontane Zone:

The tropical subzone characterized by warm and humid conditions extends from plain up to the altitude of about 1800 m. In this zone mostly sal forests, and mixed deciduous forests consisting of important plants, such as Sterculia, Terminalia Anthocephalus cadamba and Bauhinia are common. In the savannah forests, common plants are Albezzia procera, Bischofia, Salmelia, Dendrocalamus. Evergreen forests of Dillenia indica, Michelia champaca, Echinocarpus, Cinnamon, etc. are common.

(ii) Temperate or Montane Zone:
It may be further divided into upper and lower zones Lower temperate zone is the region between 1800 and 3000 metre altitudes. In the lower temperate zone, Oaks (Quercus). Michelia, Pyrus, Cedrela, Eugenia, Echinocarpus are common plants. In upper temperate zone (3000-4000 metre altitude), conifers and Rhododendrons are common. Important conifers of this region are Picea spinulosa, Abies, Larix, Juniperus, Tsuga griffithi, Tsuga brunoniana, etc.

(iii) Alpine Zone (from 4000 metres up to snow line):
Climate is humid and extremely cold. The vegetation in the alpine zone is characterised by complete absence of trees and predominance of shrubs and meadows. Important plants of this zone are Rhododendron and Juniperus. Eastern Himalayan vegetation is considered to be one of the richest vegetational units in the world and consists of several species of plants which are native of foreign countries, such as, China, Japan, Burma, Malaya and European countries.

3. Indus Plains:
It includes part of Punjab, Rajasthan, Cutch, Delhi, a part of Gujarat. Some part of this plain is now in Pakistan. The climate of this zone is characterised by dry hot summer, and dry cold winter. Rainfall is usually less than 70 cms, but in certain regions it is as low as 10-15 cms. The soil of a wide area except cultivated land, is saline. Much of the land has become desert due to excessive dryness.

Vegetation is mainly bushy and thorny Acacia arabica, Prosopis spicigera, Salvadora Capparis decidua are very common plants of this region. Salsola phoetida and Lunakh grass are found mostly in saline soils. Other plants of this botanic province are Anageissus, Eugenia, Mango, Dalbergia sisso, Albizzia lebbek, Zizyphus nummularia, etc.

Historical evidences indicate that the area was covered by dense forest some 2000 years ago, but gradual destruction of vegetation cover either by biotic agencies or by any other agency led to the development of desert in this plain. Saccharum munja, Cenchrus ciliaris, Prosopis spicigera. Acacia leucophloea, A. Senegal are the important plant species which are grown for checking the spread of desert.

4. Gangetic Plains:
This is one of the richest vegetational zones in India. This zone covers flat land of a part of Delhi, whole of U.P., Bihar, and West Bengal and also a part of Orissa. Rainfall in this zone

is from 50 cm to 150 cm. A great part of the land is under cultivation. The common crop plants are wheat, barley maize. Sorghum (jowar), Bajra, urad, Moong (Phaseolus mungo), Cajanus cajan, til (Sesamum indicum), sugarcane. Pea (Pisum sp.), gram (Cicer arietinum), potato, Brassica, rice.

In western part of U.P. annual rainfall is from 50 cm to 110 cm. Dry deciduous and shrubby forests are common in this part. Important plants of south-western part of U.P. are Capparis, Saccharum munja, Acacia arabica. In the north-western part of U.P. near Himalayas foothills Dalbergia sisso. Acacia arabica are most common plants.

In eastern gangetic plain, the conditions are cold and wet (annual rainfall, 150 cm in West Bengal). In this part evergreen forests are common. In central part, the annual rainfall is about 100 cm to 150 cm. The vegetation consists mainly of deciduous trees. Sal trees are dominant. Other common trees are Terminalia tomentosa, T. belerica. Acacia species, Bauhinia, Diospiros (Biri Ka patta or tendu) Eugenia sp., neem trees (margosa), Madhuca indica (Mahua), Cordia myxa (Lasora), Tamarindus, Mango (Mangifera indica). Ficus etc.

In Bihar and Orissa hills, Rubus, Potentilla, Fragaria (Rosaceae), Pyrus etc. are common. Mangrove vegetation is common in tidal regions in West Bengal near Sunder-ban, and Orissa. Rhizophora mucronata, R. conjugata, Sonneratia, Ceriops roxburghiana and Acanthus ilicifolius, Kandelia rheedii, Bruguiera gymnorhiza are common mangrove plants in those regions.

5. Central India:

Central India covers Madhya Pradesh, part of Orissa (now Odisha), Gujarat and Vindhya. The areas are hilly. The average rainfall per annum may be 100-170 cm. Some places are at the altitudes of 500-700 m from the sea level. Biotic disturbances are very common in this botanical province which have led to the development of the thorny vegetation in open areas. In this region teak (Tectona grandis) and sal (shorea robusta) forests are very common. Other trees are Terminalia tomentosa, Bauhinia, Mango, Phyllanthus, Ficus glomerata, etc. Among common shrubs are Mimosa rubricaulis, Desmodium, Acacia sp., Zizyphus rotundifolia and other.

Entire forest vegetation of central India may be divided into:

(i) Sal forests

(ii) Mixed deciduous forests

(iii) Thorny forests.

At Sarguja (M.P.) many species have been reported to occur. Some of them are Pyrus, Barberis asiatica, Rubus, elipticus, etc.

6. Deccan:
This region comprises whole of the southern peninsular India including Satpura and southern part of Godawari River. Average annual rainfall in this region is about 100 cm.

It may be divided into the following two subdivisions:
(i) Deccan plateau

(ii) Coromandel coast.

In Deccan plateau teak forests containing Diospiros, Acacia, Prosopis spicigera. Santalum a hum (chandan tree) and Cedrda toona are common. On rocks, Capparis, Euphorbias, Phyllunthus are common. Teak, Pterocarpus, Borassus, Foenix silvestris are also common in this area In Chhota Nagpur plateau, important species are Clematis natans, Barberis, Thallictrum and also many members of Annonaceae, Rosaceae, Compositae, Araliaceae, Apocynaceae, Lauraceae, Amaranthaceae, Orchidaceae. Some ferns also common.

In Coromandel coast vegetation consists largely of some halophytic species.

7. Western Coast of Malabar:

This is small botanical province covering Cape Comorin to Gujarat and Western Ghats .This is a region of heavy rainfall.

In this zone, four types of forests are common:
(i) Tropical forests (occur at 700 m altitude).

(ii) Mixed deciduous forests (found at the altitude up to 1600 m).

(iii) Temperate evergreen forests (occur above 1200 m altitude), and

(iv) Mangrove vegetation.

In tropical evergreen forest the trees are tall and they have root buttresses. Important species are Cedrela toona Dipterocarpus. Mangifera indica, Sterculia alata, Artocarpus hirsuta. In the mixed deciduous forests, important plants are Terminalia tomentosa, Terminalia peniculata Tectona grandis, Dalbergia, Lagerstroemia lanceolata and bamboo species, particularly Dendrocalamus and Bamboosa arundinacea. On the Nilgiri hills sub-tropic and temperate conditions exist. Important plants of Nilgiri vegetation are Rubus, Rhododendron arboreum, Barberis, Thallictrum Ranunculus, Fragaria, Potentilla. Many other herbs along with many grasses are also common.

Temperate forests commonly called as “sholas” contain Gardenia obtusa, Michelia nilgirica Eugenia species are also common. In Malabar, plants belonging to family Dipterocarpaceae’ Tihaceae, Anacardiaceae, Meliaceae, Myrtaceae, Piperaceae, Orchidaceae and many ferns are common. The west coast of Malabar region receives very high rainfall. In the coastal region mangrove plants grow luxuriantly.

8. Assam:
This botanical province is very rich in vegetation and covers valley of Brahmaputra, Naga hills and Manipur. This is the region of heaviest rainfall. Cherapunji is one of the rainiest place in the world where annual rainfall often exceeds 1000 cm. Excessive wetness and high temperature in this zone are responsible for the development of dense forests. Broad leaved, tall evergreen angiosperms and some conifers are very common in the forests.

Common plants occurring in this region are Ficus, Artocarpus, Michelia champaca, Sterculia alata. Morus species. Besides these bamboos canes, climbers, and green bushes are also common. Prominent plants in the northern forests of this zone are Alnus nepalensis, Betula. Rhododendron arboreum. Magnolia, Michelia and Prunus. Sal also occurs at Garo hills. Orchids and fern species are very rich in this zone.

9. Bay Islands of Andaman and Nicobar (India):
Islands:
These are represented by the Andaman and Nicobar islands in the east and Lakshadweep islands in the west. The Andaman and Nicobar islands are a group of more than 300 islands, which support many characteristic plants and animals. The forests range from tropical evergreen to moist deciduous and even mangroves. The Lakshadweep group of islands comprise 36 major Islands, which together from an area of 32 sq km. Many varied marine fauna are present here that include turtles, crabs, molluscs and fishes. Beautiful coral reefs are also present in this part of India.

These bay islands represent elevated portions of submarine mountains. Climate is humid in the coastal region. In Andaman, beech forests, evergreen forests, semi-evergreen forests deciduous forests and mangrove vegetation are of common occurrence. Rhizophora Mimusops, Calophyllum, etc. are common plants in mangrove vegetation. In the interior evergreen forests tall trees are common. Important species of trees are Calophyllum, Dipterocarpus, Lagerstroermia and Terminalia etc. Some part is under cultivation. The important crops are paddy and sugarcane.