CHAPTER

8

WORLD BIOMES

INTERDUCTION

The climate of an area has a profound effect on its biota. A geographical area enjoying a particular set of climatic conditions, such as characteristic regimes of temperature and rainfall and patterns of daily and seasonal changes, can give rise to a particular vegetation type and associated animal life. In other words, a particular combination of temperature, humidity and soil conditions produces a distinctive vegetation type, such as a grassland or a forest, giving shelter to its own characteristic fauna. **F. E. Clements** and **V. E. Shelford** in 1939 developed the concept of biotic units, called biomes, by classifying the world's plant formations and then associating animals with plants. **A biome or biotic region is a division of the biosphere, which incorporates a set of biotic communities within a particular region exposed to similar climatic conditions and which have dominant species with similar life cycles, adaptations and structures.** The biome concept has its origins in the **rule of climatic similarity**, according to which similar climatic environments lead to the evolution of organisms similar in form and function, but not necessarily in genetic heritage or internal structures, and to similar ecosystems. Thus, given sufficient time and similar climates in two different areas, species with similar shape and form will tend to occur. An example of this is the occurrence of desert plants with similar adaptations, even though they are geographically isolated. The saguaro cactus in North American deserts and the giant euphorbia in East Africa have been geographically isolated for more than 180 million years. Yet, these genetically unrelated species show similarity in shape, as they are tall, with green succulent stems that replace leaves and have spiny projections. Their similarities are the result of being subjected to similar climates, which imposed similar stresses and provided similar ecological opportunities. This process, by which different species evolve in different places to adapt alike to develop similar external forms and structures, and establish successfully in similar habitats, is referred to as **convergent evolution**. The similarity in the shapes of sharks and porpoises is another example of convergent evolution.

Biomes are normally described primarily on the basis of their characteristic vegetational features. However, it must be remembered that a biome comprises both vegetation and animals. Thus, it is the total community of an area and is the product of the interactions between regional climate and regional biota. Each biome is a unique regional entity, since it represents the largest land community that can be conveniently recognized as the totality of life resulting from particular physical conditions. Biomes show four main characteristic features:

i. They have their own diagnostic combination of plants and animals,
ii. They have each passed through a series of developmental stages to attain their present biotic character,
iii. They have each attained an approximate condition of equilibrium with the regional environment, and
iv. Each displays a condition of natural balance which differs from the equilibrium reached in any of the other biomes.

Biomes enable a convenient division of the biosphere on the basis of similarity of physical environments. The strong relationship between climatic conditions and the distribution of living communities is clearly demonstrated by plotting the distribution of various biomes along gradients of temperature and humidity.

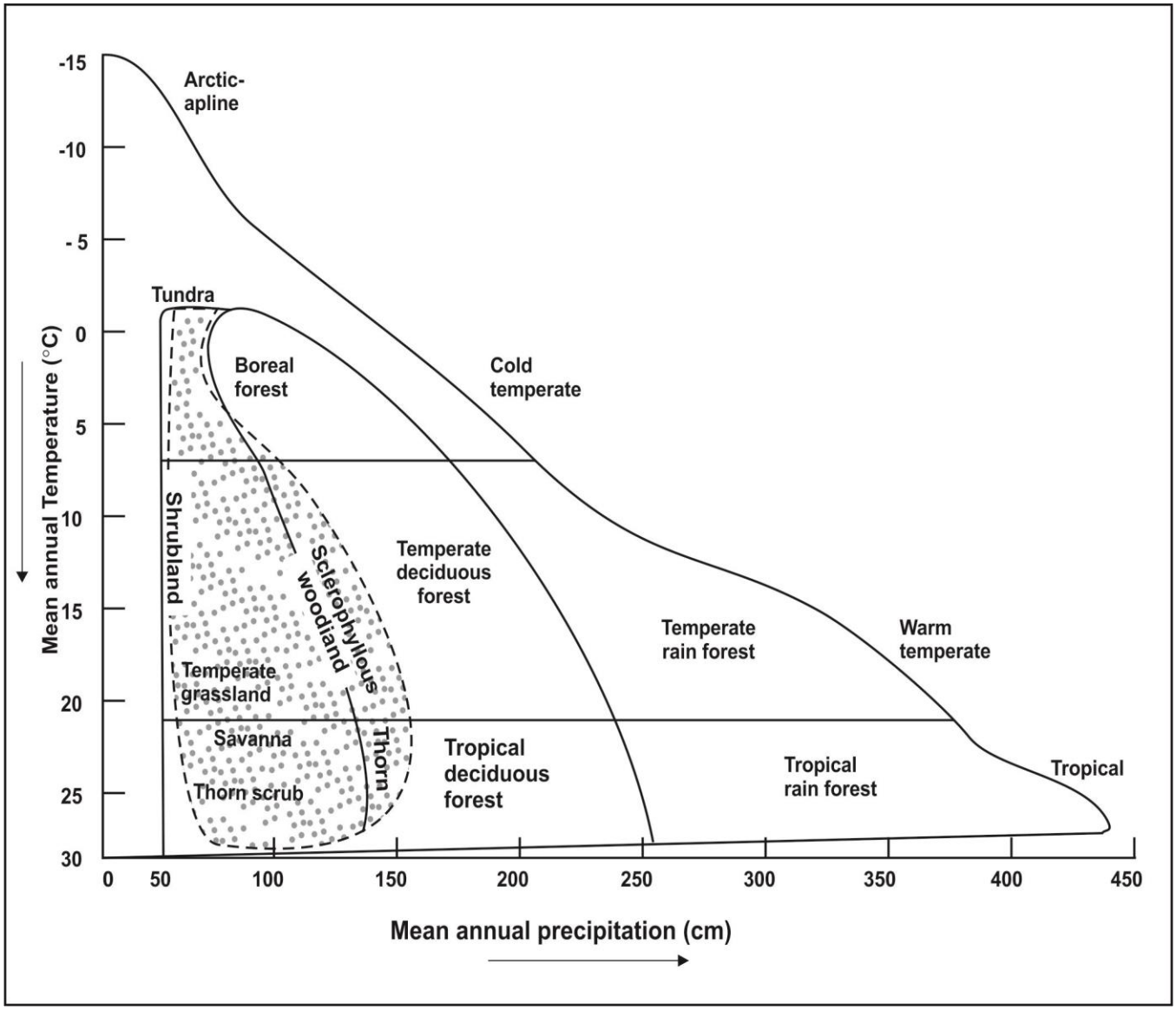


Figure 8.1 The Spatial Distribution of the Major Land Biomes in relation to temperature and rainfall.

This graph of climatic patterns is a reasonable approximation of global vegetational patterns. It shows that if the annual mean values of temperature and precipitation are known, it is possible to predict the general type of vegetation that is likely to form in a particular area. Obviously, the boundaries between biomes are not absolute. For instance, tropical rainforests occur in areas with an approximate annual temperature range of 18°C to 20°C and an approximate annual rainfall range of 250-450 cm. Deserts occur over a wide range of annual temperature, from 30°C to –5°C, as long as rainfall is less than 50 cm per year. The warmer the climate, the more rainfall is required to move from desert to another biome. In the **Figure 8.1** dashed lines enclose a wide range of environments in which either grassland or one or the other type of woodland may occur, depending on other environmental factors such as proximity to oceans, seasonality of drought, and human land-use patterns. The lack of sharp boundaries indicates that many biomes integrate with one another.

Biogeographers do not seem to agree on the number of biomes in the world, the ambiguity resulting mainly from the fact that biome is not a natural unit. If individual ecosystems are the 'species' of ecology, then biomes are the 'phyla'. Nor are there any uniform pattern of classifying biomes, as they are often divided according to one's convenience into terrestrial and aquatic biomes, or into tropical, temperate and arctic biomes, or into forest, grassland and desert biomes, etc. Usually, any where between 8 to 14 biomes are described. Traditionally, biomes

represent terrestrial or land community and only terrestrial biomes receive most of the attention. However, aquatic vegetation is by no means insignificant, in terms of scale and impact, thereby making it necessary to include them in the list of world biomes. The major biomes of the world are:

A. Terrestrial Biomes

i. Tropical Rain Forests (Selva)
ii. Tropical Monsoon Forests
iii. Tropical scrub Forest (Thorn Forest)
iv. Tropical Grassland (Savanna)
v. Tropical Desert
vi. Temperate Rain Forest
vii. Temperate Broad-leaf Forests (includes the Temperate Deciduous and Evergreen Forests)
viii. Temperate Shrubland (Chaparral, Maquis, etc.)
ix. Temperate Grassland (Steppe and Prairies)
x. Boreal Forest (Taiga)
xi. Tundra

B. Aquatic Biomes

i. Marine Biomes
ii. Freshwater Biomes
iii. Wetlands and Estuaries.

In the following map it shows only the broad distribution of biomes and it must be remembered that within each of the marked regions there are wide variations in the vegetation type. As the names of the terrestrial biomes suggest, vegetational characteristics form the primary basis on which they are identified. In other words, a biome is assumed to be the climax vegetation of that particular climatic area. However, it is not necessary that a particular area would show the climax stage, because succession is a temporal process. Therefore, many areas may have vegetation in the early or middle successional stage, making it difficult to find vegetational types typical to the area.

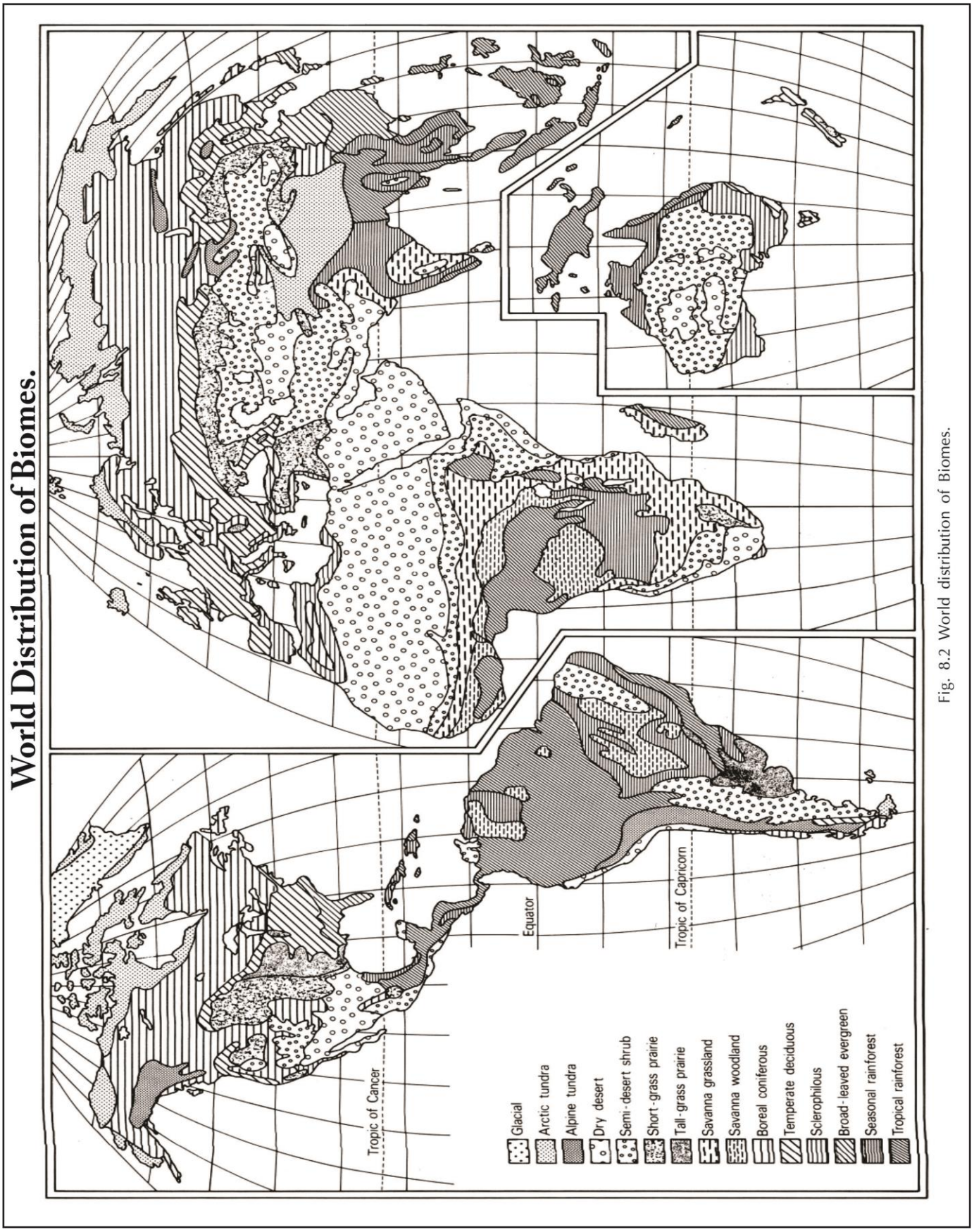


Fig. 8.2 World distribution of Biomes.

Table 8.1: Chief Characteristic Features of the Major Terrestrial Biomes, and Indications of a Latitudinal Pattern in their Occurrence.

Biomes	Physical Characteristics	Plants	Animals
Tundra	Two seasons, dry, frozen deserts, **Winter**:extreme cold and snow, **Summer:** flooding caused by snow melt, permafrost layer (permanently frozen, about 3 m below ground), **Location:** far north and far south - towards the polar ice caps, average **Temperature**: 10° Degrees Celsius **Rainfall now**: 25 cm/yr **Snow**: 10 - 20 cm/yr	No trees, dominated by mosses and lichens and grasses, some small shrubs	Insect blooms, large hooved mammals(Caribou, Musk Ox), Bears,wolves, small rodents (lemmings), migrante during the breeding season
Taiga/Boreal Forest	Long winter, short fall and spring,2-3 months of summer, wetter seasons, heavy rain and snow **Location:** coniferous forest, far nothern and far southern latitudes	Trees 5 - 10 m high, boreal forest, conifers - pine,spruce, bog plants (ferns and mosses)	Diverse array of migrants from the tropics with few resident species (Moose, Bear, Lynx, fox, voles), large insect blooms
Temperate Deciduous Forest	Four seasons, **Rainfall:** 80-140 cm/yr	Complex levels of vegetation deciduous trees, loose leaves in fall	Diverse array of migrants from the tropics and resident species
Savanna	Dry, 3 seasons **Rainfall**: 90 - 150 cm/yr **Location:** tropical to subtropical	Grasses, shrubs, trees short and (2m tall) clumped together (10 m tall)	Large ungulates, large predators
Temperate Grassland	Temperate and some subartic grassland (extreme northern Prairies-steppes and some extreme southern grasslands-Pampas of Argentina) **Rainfall:** 25-70 cm/yr	Grasses	Large ungulates
Chaparral	Mild wet winter followed by hot, dry, summer many plants dependent on regular fires associated with Chaparral **Location:** near coastlines (California, Chile, Mediterranean)	Short trees and shrubs	Diversity of mammals, birds, insects, etc. that like dry habitats
Desert	Very dry, **Rainfall:** less than 25 cm/yr **Location:** primarily equatorial but some reach into temperate regions	Cactus, sagebrush, creosote and shrubs	Small rodents, reptiles
Tropical Rainforest	Very wet-heavy rainfall, **Soil**: poor in nutrients, **Temperature:** constant throughout the year (wet and dry seasons) **Location:** equatorial, 23.5° N latitude -23.5° S latitude	Large trees- broad-leaved evergreens,epiphytes, not much forest floor vegetation (little sunlight), canopy 30 - 40 m above ground	Highest diversity of animals
Aquatic Biome	Freshwater and Marine Biomes		

Marine-Pelagic Zone	Deep ocean, dependent on upwellings	Algae	Various birds, large mammals, fish
Marine-Benthic	Ocean floor, no light	None	Detritus feeders, predatory fish
Marine-Estuaries	Where rivers flow into the ocean, mix of saltwater and freshwater, marshes rich in plants and animals	Aquatic vegetation, marsh plants	Rich variety
Marine-Intertidal zone	Shoreline to shallow waters	Algae	Marine worms, clams, oysters, crustaceans
Coral Reefs	Tropical oceans	Algae	Coral, fish

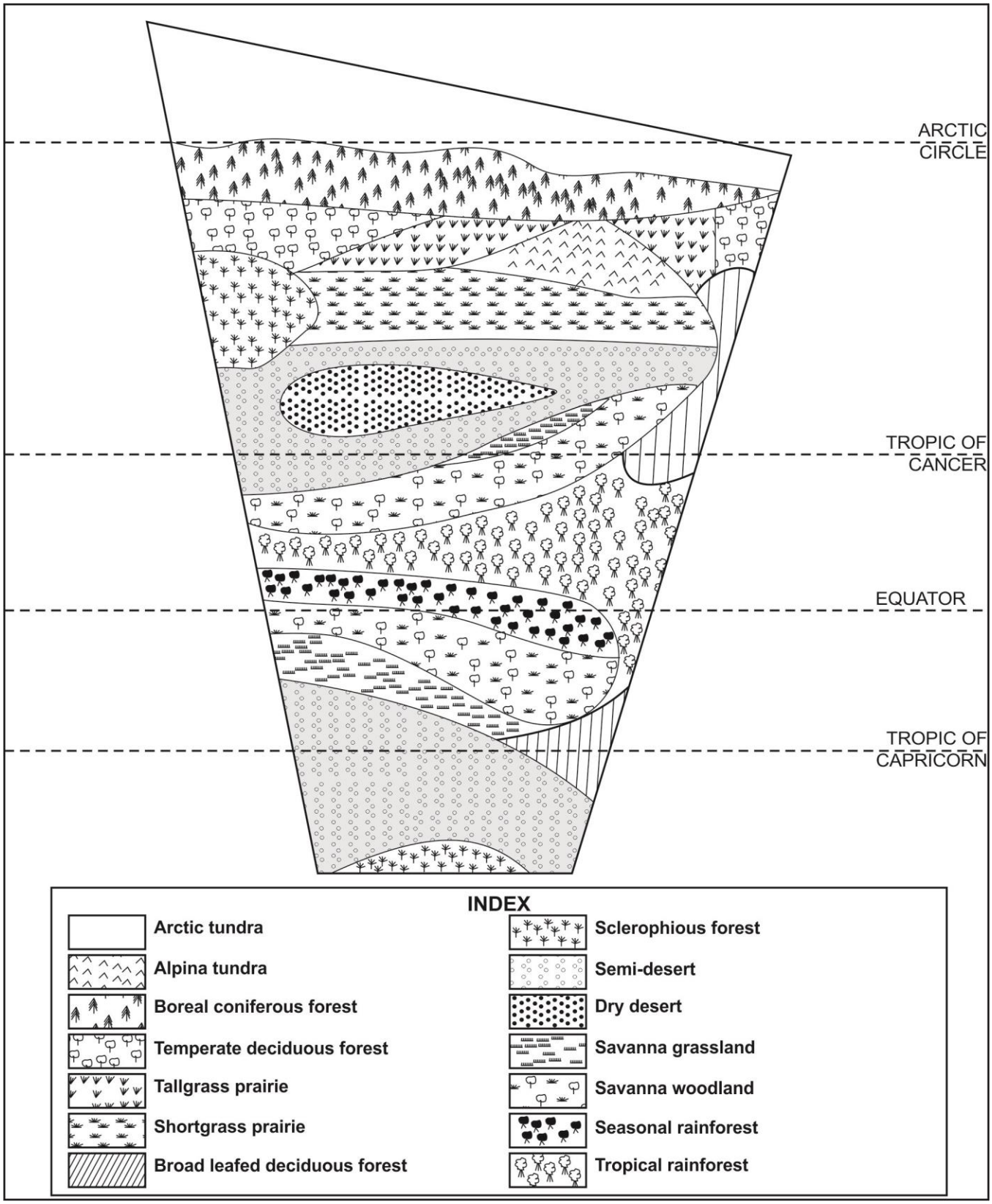


Figure 8.3: Vegetation Formation-type in a Hypothetical Continent.

The following section looks at the characteristics – combination of climatic and vegetational condition – of various biomes.

TROPICAL RAIN FORESTS (SELVA)

Tropical rain forests (Equatorial forests) grow in the warm and humid tropics, where seasonal changes are minimal and rainfall is distributed throughout the year. They occur near the equator, and once formed a worldwide belt about the equator. The typical areas where they occur have mean annual temperature of about 26°C, which rarely goes below 25°C, and the difference in temperature through the year is less than 4°C. Annual rainfall could range from 150 to 400 cm, and not less than 10 cm rainfall occurs in any month for two out of every three years. Most of the tropical rain forests are located in wet lowlands below 1000 metres in the equatorial latitudes between 0° and 8° north and south of the equator. They can be found in South and Central America, West and equatorial Africa, South-east Asia, Indonesia and North-east Australia. The single largest area of tropical rain forest is in the Amazon basin.

Tropical rain forests contain the greatest diversity of life of any of the world's biomes. The continual combination of warmth and moisture leads to the continuous growth of plants, which support a greatly diverse animal life. There may be upto 1500 species of flowering plants and 750 species of trees in a 10 km^2 area of tropical rain forest. The vegetation of these forests show many characteristic features:

i. Rich and luxuriant growth,
ii. Trees grow very rapidly and continuously due to the presence of ideal climatic conditions, that is, high temperatures, heavy rainfall and high humidity throughout the year.
iii. The trees grow to great heights (50 metres or more). Though they are huge, they have shallow roots and wide bases (called buttresses) that support their massive weight.
iv. The rich diversity would mean that the trees seldom grow in stands of one variety. Infact, one species of tree may be separated from a similar one by hundreds of different species.
v. The tops of trees form a dense canopy. Most of the photosynthesis occurs in the canopy and many trees develop aerial roots in the canopy, which absorb nutrients.Many trees in the canopy are covered by plants growing on others, the epiphytes, such as orchids, ariods and bromeliads. Because of canopy very little light can penetrate to the forest floor and therefore, very little undergrowth is found.
vi. Many trees exhibit cauliflory, i.e., trunks bearing flowers or fruits.
vii. Along the river banks and in clearings, where the sun does reach, there are ferns, bushes and creepers.
viii. Many of the tall trees are used by climbing plants (lianas) such as rattan, which are also striving to reach light and air, reach to the tree tops.
ix. As seasons are absent, each plant follows its own life cycle independently. Thus, at any particular time of the year, there may be trees bearing fruit, others flower, some shedding their leaves and others growing new leaves. Therefore, the trees in these forests do not shed leaves at the same time and are called evergreen forests.
x. The vegetation displays at least three distinct layers resulting in the stratification of both vegetation and animals. The layers are:
    (a) **The Uppermost or Emergent Layer** consists of trees over 60 to 80 m in height. In this region the trees are tallest. They are widely spaced and hence develop wide crowns of broad evergreen leaves. The crowns rise above the rest of the forest to form a discontinuous canopy. These trees have straight, smooth and narrow trunks, with branches appearing only near the crowns. Large buttress roots are required for support due to their height. Climbing plants, like creepers, vines and lianas cover most tree trunks.
    (b) **The Intermediate Layer** consists of smaller and younger trees about 50 m in height. This layer forms another lower discontinuous canopy. Since they are not widely spaced they develop narrower crowns. Ferns, orchids and lianas are common. The upper two layers together form an almost complete canopy and shut out light from reaching the forest floor.
    (c) **The Lower Layer** consists of very young trees, ferns and shrubs. It forms a continuous layer and is well-defined. Except in the clearings and along the river banks, there is little undergrowth, because insufficient light reaches the floor of the forest. On the forest floor there is a mass of decaying vegetation. This represents the accumulation of innumerable years of leaf fall.

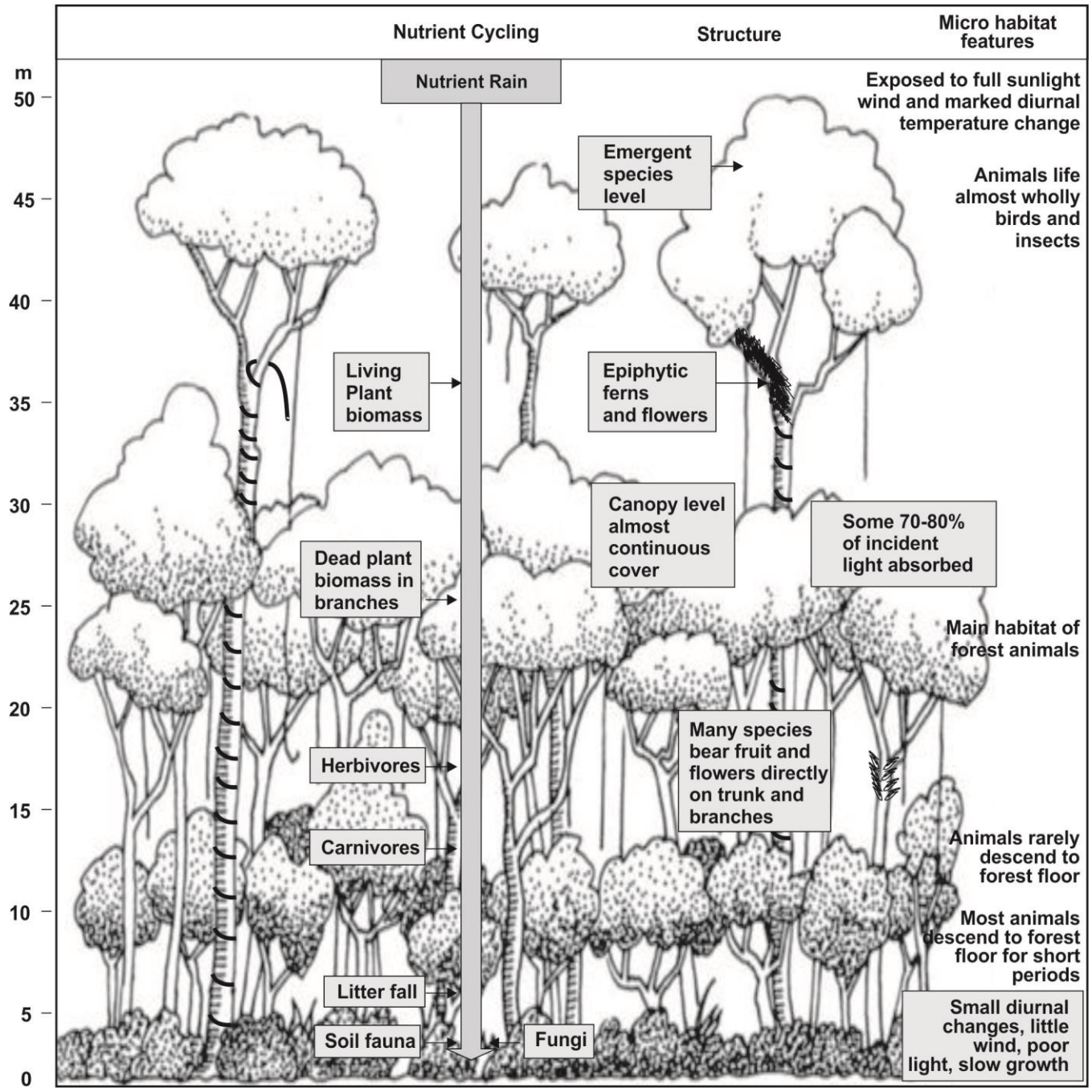


Figure 8.4: Vertical Stratification of a Tropical Rain Forest. There may be two to three additional layers in many rain forests.

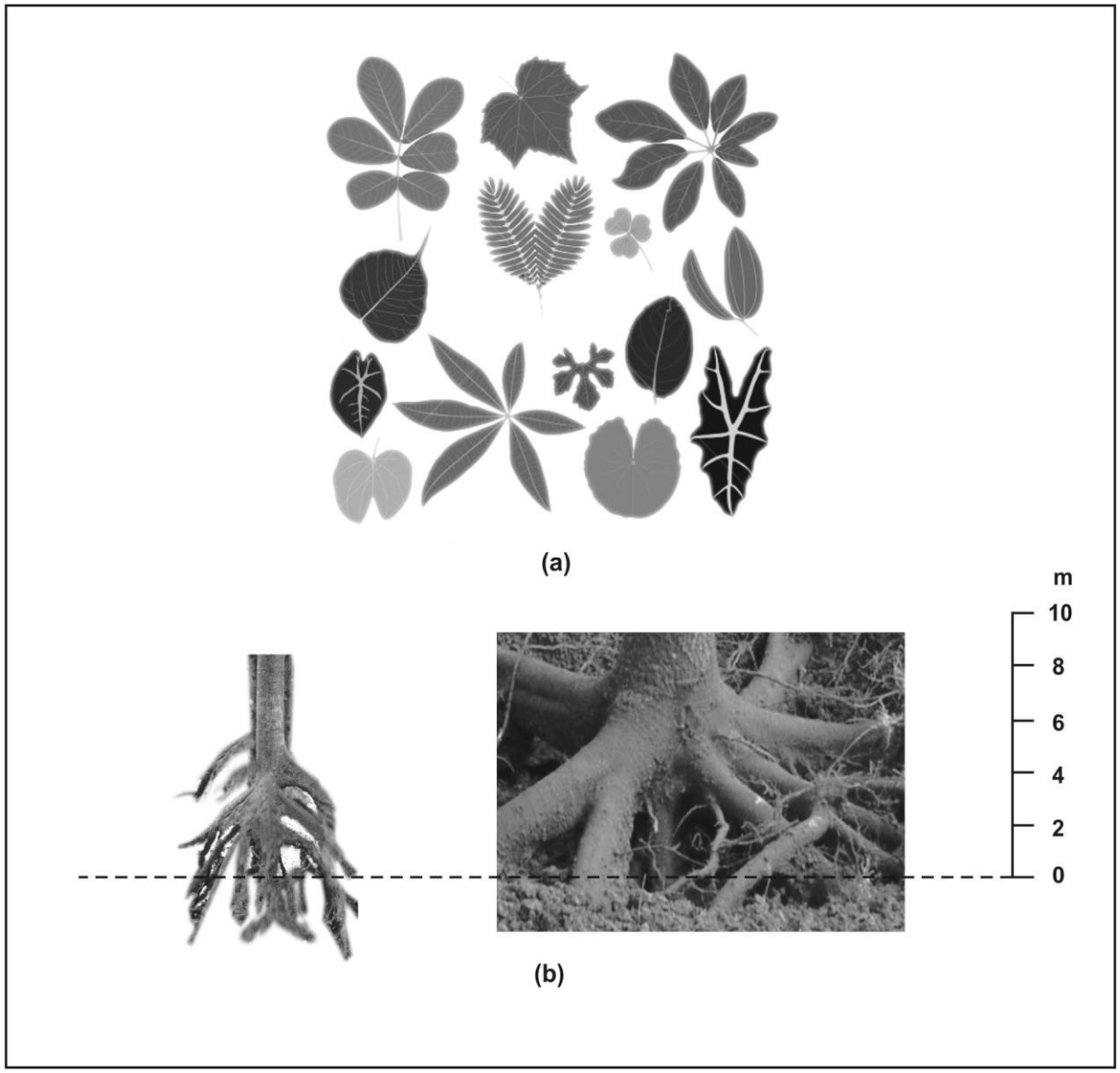


Fig.8.5: Some features of tropical plants: (a) Various is shapes of leaves with conspicuously differentiated drip-tips; (b) Stilt roots (left) and heavy buttresses (right).

Elfinwood (Elfin forests)

These are dwarfed forest vegetation found high up on tropical mountains in Africa, South America and New Guinea. They resemble tropical rainforests in miniature and get their name from the mythical little people called elves recorded in many European fairy tales. At the high altitudes where Elfinwoods occur, the climate is non-seasonal and it is cold. Lower temperatures and lesser rainfall lead to the formation of small and stunted trees, with contorted branches and a low canopy of broad evergreen leaves. Sometimes, they are less than a meter in height with horizontal, rather than vertical forms of vegetation. The branches are often covered with curtains of lichens, mosses and ferns. The relatively high humidity encourages these epiphytes to grow.

The animal life in tropical rain forest also exhibits distinctive characteristics:

i. Since food production occurs mainly in the canopy, there is an abundance of browsers that can climb, principally primates.
ii. Heavy browsing animals on the ground are less numerous.
iii. Detritivorous animals, particularly ants and termites are abundant. They show very high decomposing activity.

iv. Insects and spiders are large-sized.
v. Snakes and other reptiles are abundant.
vi. Mammals are adapted to arboreal life.

Animal life in the tropical rainforest shows a high degree of stratification, and six distinct feeding strata have been identified:

i. Those feeding above the canopy, consisting largely of insectivorous and some carnivorous birds and bats.
ii. Top of the canopy group, feeding on leaves, fruit and nectar. Include a variety of birds, fruit bats and other species of mammals.
iii. Those, which feed below the canopy, mainly in the zone of the trunks. Include many flying animals like birds and insectivorous bats.
iv. Mammals, which range up and down the trunks in the middle canopy. They keep entering the canopy and the ground zone to feed on the fruits of epiphytes, on insects and on other animals.
v. Large ground animals with or without climbing ability. Mainly comprise herbivores and their carnivores.
vi. Small ground and undergrowth animals make up the final stratum. Includes insectivorous, herbivorous, carnivorous and mixed feeders.

The soils of tropical rain forests are poor in nutrients, partially due to the heavy demand for them by the growing plants. Because of the warm moist climate and hordes of decomposers, fallen leaves, fallen trees and dead animals decompose quickly and this rapid recycling of scarce soil nutrients explains the lack of plant litter on the ground.

The epiphytes form microhabitats high above the ground, with pockets of organic soil trapped in the leachate from rain percolating through the canopy. In fact, some trees have roots growing upwards to reach these nutrient resources.

Despite such a vide variety of tree species, the soils in these forests tend to be acidic and low in nutrients. The reason is that most mineral nutrients. The reason is that most mineral nutrients released by decomposition are absorbed quickly and stored by trees, vines, and other plants.

TROPICAL MONSOON FORESTS

There are areas within the humid tropics with a marked dry season and such areas are normally said to have a monsoon type of climate. The incidence of seasonal drought may last for several months during which trees may lose their leaves. These forests are often found where monsoons provide seasonal rainfall, including many areas in India, South-east Asia, West and East Africa, South and Central America, West Indies and Northern Australia. Tropical monsoon forests occur sandwiched between the tropical rain forests and the tropical grassland.

There are wide variations in the vegetation types in the tropical monsoon forests, since the monsoon climate regime itself varies considerably in different areas. Nevertheless, the vegetation displays certain general features:

(i) Monsoon forests are not as luxuriant as rain forests.
(ii) They do not have continuous canopy, abundance of climbers or tallness of trees, like the rain forests.
(iii) Most of the trees are deciduous (shed their leaves during the dry season) and are widely placed. This allows a better penetration of more sunlight, which supports a richer diversity of plant life at the ground level.
(iv) Unlike the rain forests there are only two layers or tiers in these forests:
   a. **An upper layer** of tall trees (growing to 30 metres or more), like the teak or sal.
   b. **A lower layer** of evergreens with rich undergrowth.
(v) The occurrence of a dry season imparts a seasonal rhythm to plant growth. There is a halt in growth during the dry season, when the trees flower and shed their leaves. Shrubs in the undergrowth also cease to grow during this time.
(vi) The number of species of trees is less than in the rain forests, and with the exception of teak and sal, very few of them are commercially useful.

(vii) Trees have more branches, which spread out to give wide crowns. They do not have buttress roots. Many of them have large oval-shaped leaves.

(viii) Stands of one variety are extremely common, like the teak forests of Myanmar, bamboo stands in Indo-China, the sal of India and eucalyptus of northern Australia.

(ix) Since these forests are more open, sufficient light reaches the forest floor, resulting in a thick undergrowth. It consists of woody thickets and shrubs.

Monsoon forests are also described as tropical semi-evergreen forests because only about 30 per cent of the trees lose their leaves in the dry season, i.e., there is no total leaf loss in these forests. Most of the monsoon forests, which covered much of the Indian sub-continent and Myanmar, have been modified following human occupation. Remnants of the original forests are, however, found in many parts of India and in South-east Asia.

TROPICAL SCRUB FOREST (THORN FOREST)

As the climate gets drier and the soils poorer, the monsoon forests grade into the thorn forest or thorn wood. It is a transitional vegetation type, exhibiting some of the features of semi-desert and the savanna grassland. However, they are distinguished from the savannas in their lack of grasses. Thorn forests are found in areas in Central and South America, in Africa, in South-east Asia and in Australia.

The thorn forest vegetation has the following general features:

(i) With the decrease in annual rainfall and the lengthening of the dry season, the trees become more deciduous.

(ii) Trees are lower, bushier and more gnarled.

(iii) The shrubs are chiefly xerophytic.

(iv) Many of the bushes have tough leaves and many bear wicked thorns and spines (e.g., *Acacia*).

TROPICAL GRASSLAND (SAVANNA)

Many tropical areas receiving a wet and dry climate are covered by vegetation types that vary from unbroken grassland without trees, to grasslands with a nearly complete shrub and tree cover. The term 'savanna' meaning grasslands or plains in Spanish, is used to describe this wide array of tropical grassland vegetation. Savannas lie between the tropical forests and the deserts. This area is characterized by the seasonal alternation of wet and dry conditions. A distinct cool dry winter season is followed by increasing temperature and then by heavy rains in summer. Most savannas receive about 76 cm to 100 cm of annual rainfall, but some get only less than 25 cm while some others receive in excess of 150 cm.

The annual mean temperature in savannas is 21°C, but the summer temperatures may go as high as 32°C. The alternating dry seasons limits tree growth. Moisture is the major determinant of savannas, and hence the type of savanna in an area is a function of rainfall and soil texture (clay retains more moisture than sand). Consequently, different types of savannas can be identified, such as:

(i) **Dry savanna or scrub savanna:** Consists mainly of low thorn trees and shrubs; occur in areas where the dry season is as long as nine months.

(ii) **Savanna parkland:** Tall grasses dotted with trees such as acacia; where the dry season lasts six to seven months.

(iii) **Savanna woodland:** Contains more trees and shrubs and less grass. Occurs in areas where the dry season is only about three months long. They occur more on the equatorward side.

(iv) **Savanna grassland:** Very little or no trees, only scarce shrubbery, occur mainly in clayey soils with moderate rainfall.

(v) **Wet and swamp savannas:** In clayey areas which receive rainfall in excess of 150 cm.

Savannas are found most extensively in Africa, more than two fifths of this continent is covered by savannas. They are also found in Australia, South America and in many areas in south and south-eastern Asia. Majority of the African savannas are the 'high-grass, low-tree' type, the rest being the 'acacia-tall grass' type, where the grass cover is short and discontinuous. The plateau areas of South America and the Orinoco Basin are mostly covered by savannas. The Brazilian tropical grasslands are generally called *campos*, while those in the Orinoco Basin are called *llanos*. In India, savannas are found in many parts of the north-west and in the western and south-eastern parts of the Deccan.

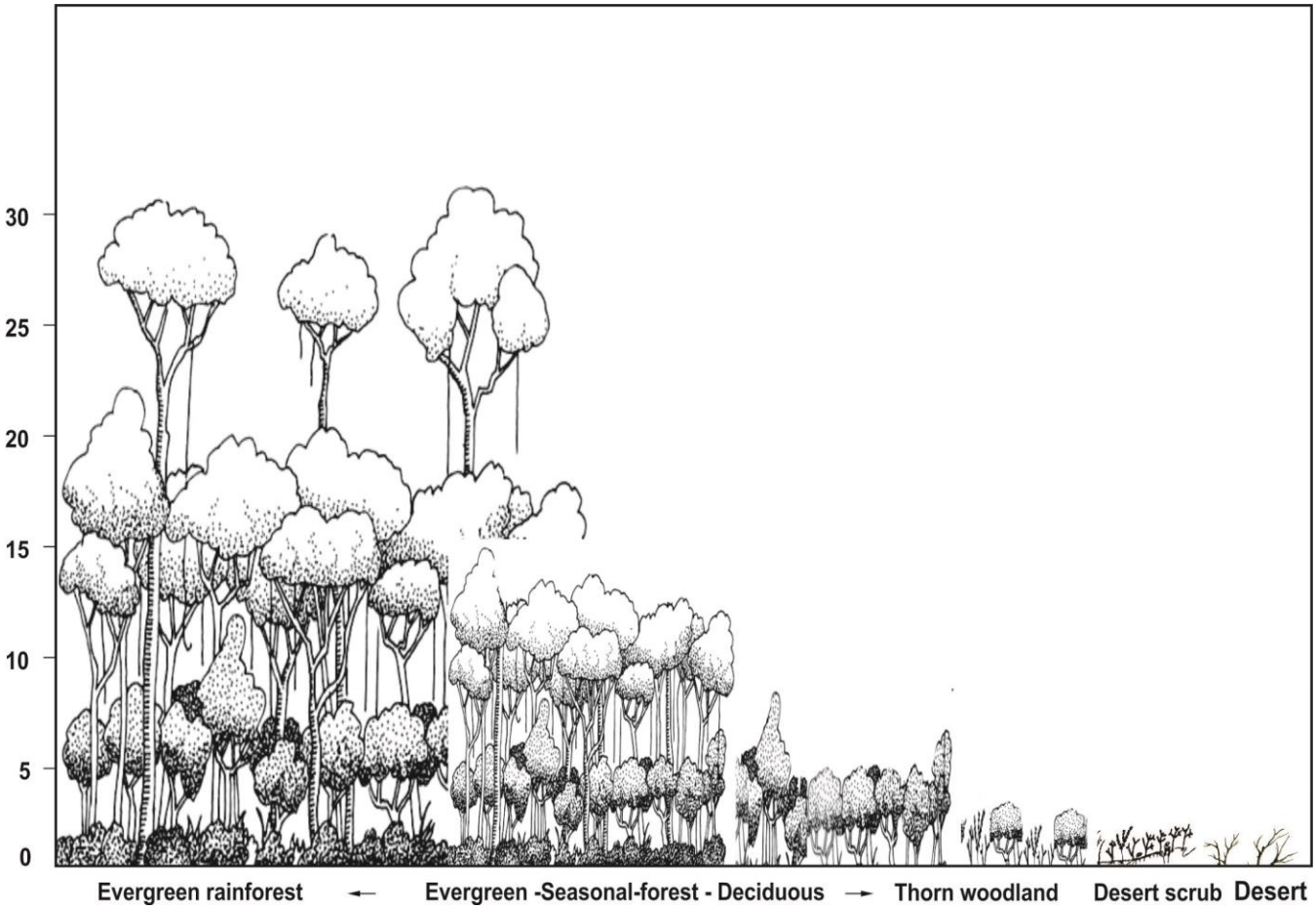


Fig.8.6: Profile Diagram through the types of Tropical Forest from Rain Forest to Desert.

Vegetation in the tropical grasslands shows much regional variation. The general features are:

(i) Grasses dominate, although, woody perennials may be found scattered in the landscape.

(ii) Grasses on the dry savannas grow only a few centimeters high, whereas those on the wet, humid areas may grow very tall (upto 3 metres).

(iii) Most grasses grow in clumps and do not form a continuous cover.

(iv) Many non-woody plants, including daisies and peas grow among the grasses. Thorn bushes, shrubs and succulents like cacti are found in the scrub savanna.

(v) Common trees include acacias, baobabs and palms. Trees are 6-12 m in height, strongly rooted with flattened crown.

(vi) Tree growth is limited by the dry season following the summer rains. The main growing season is summer with its high temperatures and heavy rain, which promote rapid and luxuriant growth. The cool and dry winter season limits growth of all plants as they become dormant. The trees stop growth and shed their leaves, while the grasses wither, turn brown and die down.

(vii) Trees have drought-resistant features to survive drought. For instance, acacias have umbrella-shaped crowns to protect their roots from sun's rays, baobabs store water in their trunks, roots of many trees penetrate deep and many of the trees have either leathery leaves or they shed leaves in winter.

(viii) The dry spell is frequented by bush fires, which destroy young trees. Vegetation, therefore, shows adaptations to resist the reneging effects of fire. For example, grasses have extensive root systems that survive the fires and send up fresh shoots as soon as the rains return. Similarly, trees have thick bark which insulates the living cambrium from the heat of the fire. Seeds, like those of eucalyptus in Australia have hard shells or cases, which resist heat. In fact, some trees require occasional forest fires in order to break open their seeds for germination.

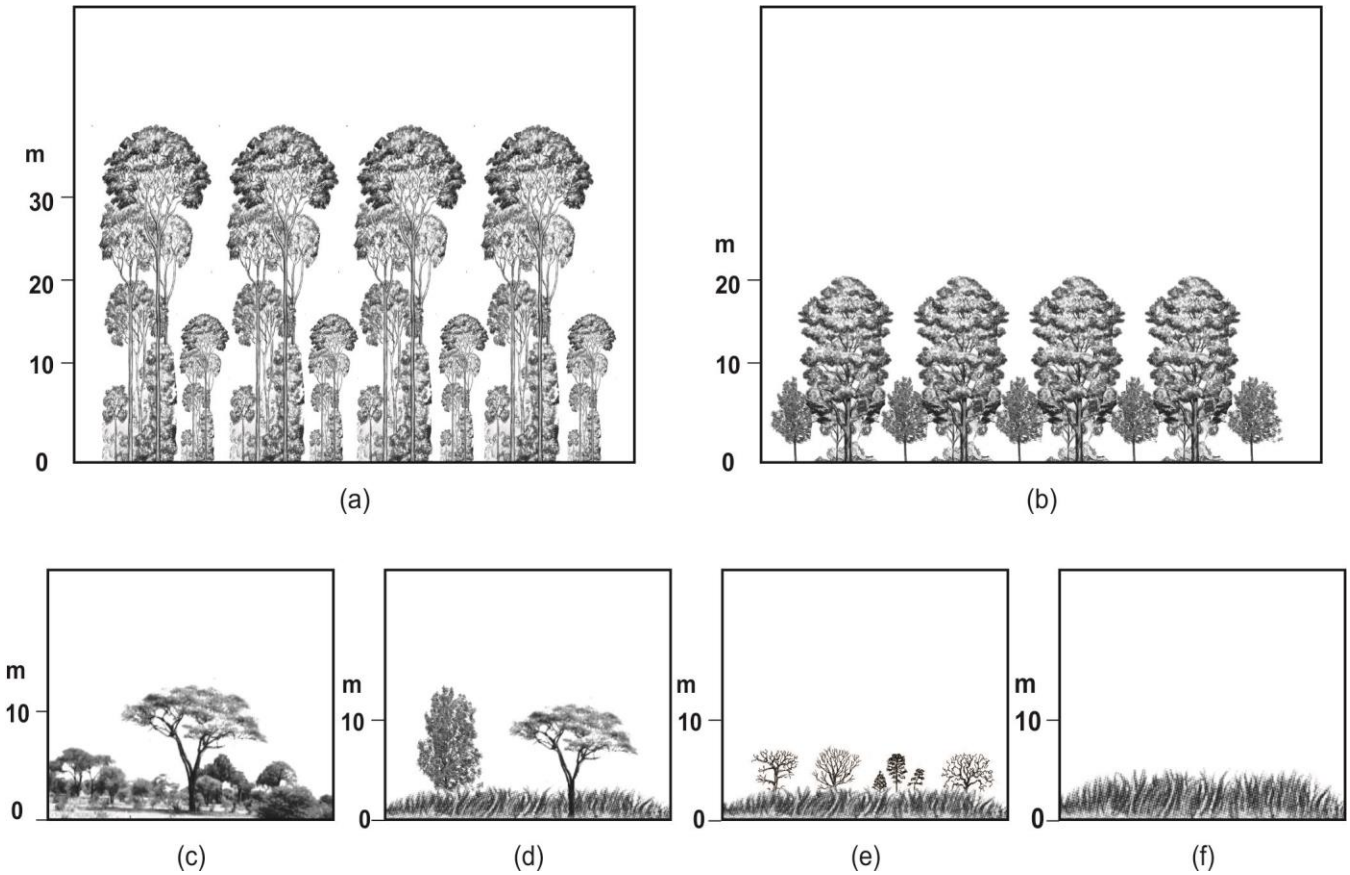


Fig.8.7: Some of the range of vegetation types found in the seasonal tropics: (a) semi-evergreen seasonal forest; (b) deciduous seasonal forest; (c) savanna woodland; (d) tree savanna; (e) scrub savanna; (f) grass savanna.

Savannas are abundant in animal life due to the abundance of easily digestible food and less demanding climatic conditions. The number of primary consumers (herbivores) is very high, leading to the existence of a variety of carnivores, which prey upon the herbivores. The following generalisations can be made on the savanna fauna:

(i) Visible fauna comprise grazers, browsers and carnivores.

(ii) Large herds of grazing mammals, like zebras, antelopes, wild beast, buffalo and gazelles, are very common.

(iii) Common browsers include giraffe, impala, eland and gerenuk.

(iv) Hoofed mammals adapted to running on the flat plains dominate.

Caatinga, the South American Thorn Forest

The north-eastern shoulder of Brazil has an extensive area of thorn forest, called the Caatinga, which means, "light forest." The total annual rainfall is not very low (760 to 1524 mm). However, the rainfall is highly erratic, not dependable and tends to come down in a few violent downpours of short duration. There are periods of drought alternate with heavy rains. Between May and October, a long, hot dry season prevails with temperatures in excess of 27°C and high rates of evaporation. These conditions lead to the formation of drought resistant vegetation of low-growing, bushy trees and thorny shrubs, mixed with succulents. Caatinga vegetation varies greatly with the seasons. It is green and luxuriant during the rainy period. As the dry season sets in, the grasses wither and the trees lose their leaves, and at the end of the dry season, the Caatinga has a bare, harsh and hostile appearance. Cacti, xerophytic palms, thorny plants, etc. are very common.

(v) The wide variety of carnivores supported by the abundant herbivores include, lions, hyena, jackals, leopard, cheetah, African wild dog, etc.

(vi) The large number of carnivores support a variety of scavengers, dominated by vultures.

(vii) Savannas contain many species of birds, reptiles, rodents and insects.

(viii) Many animals use camouflage to avoid predators or to confuse their prey, e.g., the stripes of zebra, the tawny colours of lions and antelopes, spots of cheetahs, etc.

(ix) The herbivores are adapted to escape the sharp–clawed and sharp-toothed predators by their fleet-footedness, especially in the ungulates.

The large number of animals in the savannas normally does not cause as fierce a competition for food as in many other biomes. This is due to many animal specializations, such as the use of different habitats and vegetation types, differences in grazing and browsing heights and the use of different dry season refuges. For instance, grazing ungulates are known to migrate long distances across the plains, thus, not restricted by the availability of food in a particular part of the savannas.

TROPICAL DESERT

Deserts are terrestrial areas where the rate of evaporation exceeds that of rainfall. They are characterized by low moisture levels, and precipitation that is both infrequent and unpredictable. Deserts are normally classified on the basis of rainfall into:

(i) **Semi-deserts:** Between 15 and 40 cm of precipitation in a year.

(ii) **True deserts:** Between 7 and 12 cm of annual rainfall.

(iii) **Extreme deserts:** Below 7 cm of rainfall.

Deserts with less than 2.5 cm rainfall support no vegetation, while those with 2.5 cm to 5 cm rainfall may support sparse vegetation.

Deserts are found throughout the world, as they occupy nearly 26% of continental area. They occur mainly in the sub-tropical zone as two distinct belts between 15° and 35° latitude in the Northern and Southern hemisphere, around the Tropic of Cancer and the Tropic of Capricorn. The tropical deserts can be found in Africa, South America, Asia and Australia. The major deserts are the Sahara in North Africa, Arabian deserts, Namib and Kalahari and Southern Africa, Gobi to the north of the Himalayas, the coastal Atacama Desert of Peru and Chile, and the Australian deserts.

Deserts are formed due to multiple natural causes, a major cause being the movement of air masses over the earth, resulting in the alteration of the course of rain. Another cause is the effect of mountain ranges, which impart a rain shadow on their lee side. For instance, the High Sierra and the Cascade Mountains intercept rains from the Pacific and maintain arid conditions in North American deserts. Deserts are also formed when an area is far too remote from the source of oceanic moisture, like the Gobi and Sahara; the winds lose all moisture by the time they reach these areas.

The main general features of deserts are:

(i) Low rainfall and high evaporation;

(ii) Wide daily range in temperature; hot by day and cool by night;

(iii) Upto 90 per cent of solar insolation heat the ground because low water content in the atmosphere allows easier light penetration;

(iv) Rain, when it falls, is often heavy and unable to soak into the dry earth;

(v) Soil, unprotected by vegetation, erodes rapidly by violent storms and wind;

(vi) Vegetation, usually, is a matrix of shrubs (woody-stemmed and soft brittle-stemmed shrubs), numerous ephemerals, and a wide assortment of other plants, such as cacti, yucca and small trees.

(vii) Both animals and plants are adapted to water scarcity by means of drought-evasion or drought-resistance.

Deserts pose very stressful challenges to all living organisms and they need to adapt to the dry conditions in order to survive. However, despite the extremely trying conditions, deserts are known to harbour a large number of species of animals and plants. Desert vegetation primarily consists of various species of grasses and shrubs. Grasses grow in clumps with bare earth in between. All desert plants are adapted to drought conditions and high evaporation rates, and are hence called as **xerophytes**. The plant responses to aridity are based on two strategies, either they try to survive as ephemerals or they survive as perennials. Ephemeral (= short-lived) plants complete their life cycle in just a few weeks. They are adept at taking advantage of sudden rains, by germinating, growing, flowering and seeding within the space of just 20-30 days. Their drought resistant seeds can then lie dormant until the next rains. Due to their short life-cycle, they form dense and colourful stands of vegetation on an otherwise barren landscape, immediately after the first few showers.

The desert perennials includes the five distinct groups of plants :

a) **Those which remain dormant** for long periods awaiting the infrequent rain showers. The seeds of these plants are protected by an impervious coat, which enables them to survive for years without water or they survive as underground bulbs or corns. Immediately after rain, the plant comes to life, and rapidly completes its life cycle, before dying down. These are called **Geophytes**.

b) **Plants which have deep roots**. Many desert perennials have an extensive root system, which penetrate deep into the ground to reach the ground water levels, such plants are referred to as **phreatphytes**. Some of them are known to penetrate to depths of more than 17 metres in search of water supplies. They are usually found on the floors of depressions or wadis. They conserve moisture by reducing transpiration. This is achieved by growing either narrow waxed leaves, or thorns instead of leaves.

c) **Succulents,** which depend on the infrequent showers of rain, and store water in their leaves and stems. The succulents are adapted to surviving above ground by minimizing water loss through transpiration. They achieve this by having thick cuticles, low surface area to volume ratio and sunken stomata, which open only at night to take up carbon dioxide. Other adaptations for minimizing transpiration include shedding of leaves, waxy coating on leaves, very small, narrow and scaly leaves, and ridged stems. Succulents, like cacti, store water in their leaves and stems. The spines or thorns of desert plants guard them from being eaten by herbivores.

d) Finally, there are **plants which can withstand drought**, despite the fact that they have neither deep roots nor storage facilities. Such a plant is the creosote bush of North America, which relies entirely on rainfall or on the high humidities, which characterise the deserts at night.

e) In areas of saline soils, only plants which are able to adapt themselves to these conditions can survive. Such plants are known as **halophytes**.

Animal life also exhibits various adaptive features in the desert environment. An important strategy is to escape or evade the stressful conditions during the day. Some of the characteristic features of desert animals are:

(i) **Seasonal migration** of animals to evade the most severe conditions.

(ii) **Nocturnal habit** (**active during night time**): The wide difference between day time and night temperatures is used by these animals to their benefit. They hide under stones, cracks or bushes during the day and come out only when the temperature drops after sunset.

(iii) Some of them can pass over the most difficult times in a state of dormancy; called **aestivation**.

(iv) Jack rabbits and foxes have large ears, which help in more efficient heat loss.

(v) Kangaroo rats can survive for months without drinking water. They depend on the minute quantities of hygroscopic water in their food, and on their own metabolic production of water. They also conserve water by producing a highly concentrated urine.

(vi) Camel is another animal that has perfected the art of living in desert conditions. They have a low surface area to body size ratio and lower internal heat production, which helps in the slower accumulation of heat during the day. During the night the accumulated heat is slowly released.

Plant Adaptations in the Desert

Plants have adapted in many different ways, such as:

Ephemeral lifestyles: some desert plants live for only a very short period of time, normally a few days at most. Their seeds remain dormant in the desert sand for long periods of time (often years), and they quickly germinate and bloom when the infrequent rain falls.

Root systems: many woody desert plants have developed root systems that are capable of reaching whatever moisture is available in the sand. Some have very long root systems, which can exploit deep water sources (the mesquite from the south-western USA, for example, has tap roots up to 10 m long). Others (such as, the creosote bush) have shallow spreading roots which can exploit dew and occasional rain.

Leaves: most desert plants have small leaves, and this adaptation conserves water by limiting the surface area from which transpiration can occur. Some desert plants shed their leaves during dry periods, and plant stems then take over photosynthesis.

Water storage: some desert plants are succulents, which store water in their leaves, stems and roots. Cacti such as the rounded prickly pear and the tall, straight saguaro - which have fleshy bodies, stems or leaves that act like sponges - are classic examples.

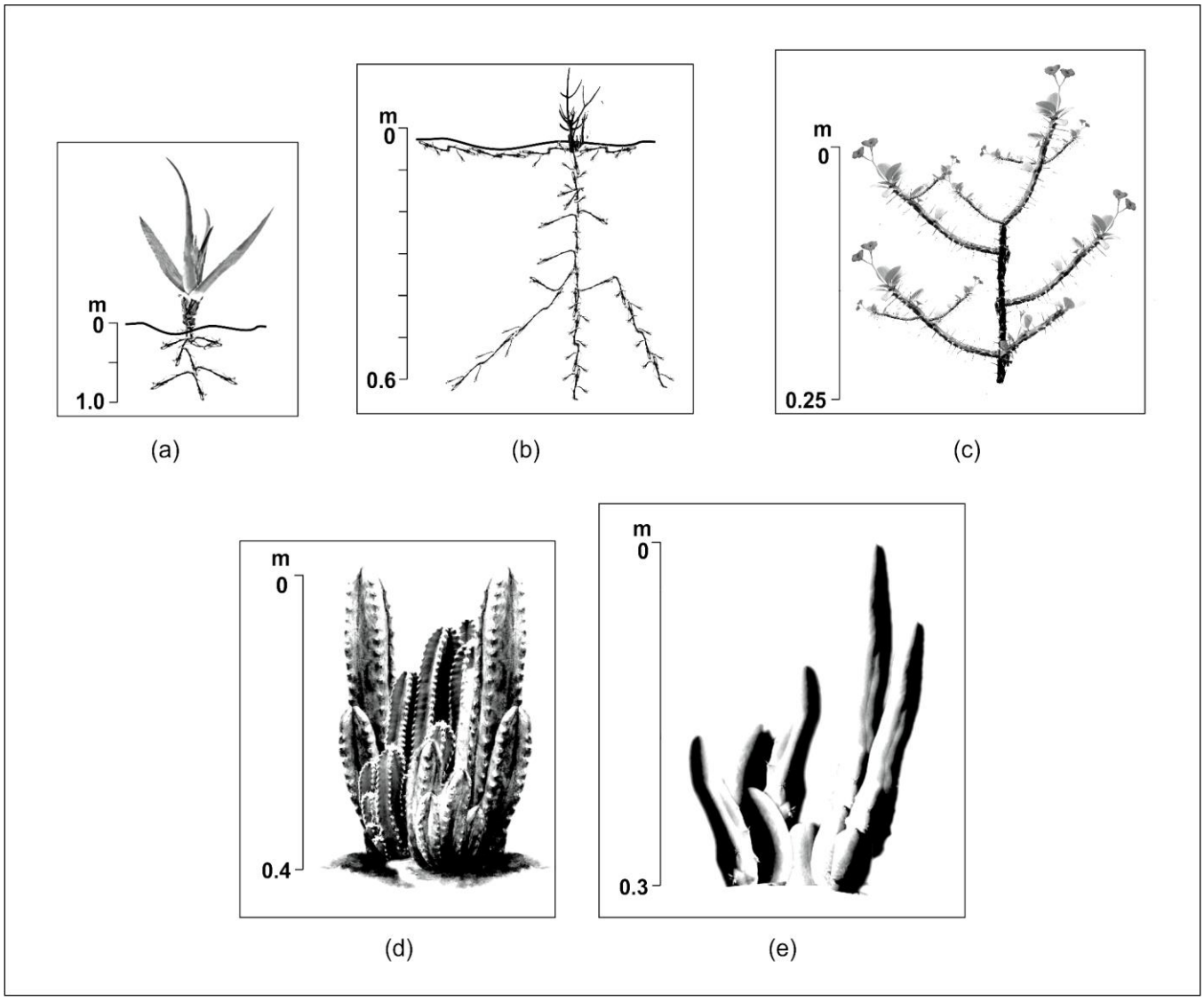


Figure 8.8: Some forms of adaptation of desert plants to the rigours of the environment:

- ***(a) A succulent plant, which can store a great deal of water and so can rely on near-surface roots collecting rain from sporadic precipitation events;***
- ***(b) An acacia bush of a type very characteristic of desert margins, which adopts a dual strategy of having subsurface roots to collect any rnoisture sporadically available from rainfall, together with a very deep rooting system stretching down to permanently available groundwater in the subsoil and rock;***
- ***(c) A plant with very small leaves in relation to the size of the branch (0.25 cm), thereby limiting evapotranspiration loss;***
- ***(d) The thorny euphorbia of the Namib Desert in South West Africa; and***
- ***(e) Its equivalent in North America, the cactus.***

Animal Adaptations to the Desert

- Some amphibian species (vertebrates that usually live on land but breed in water) which remain dormant for long periods of time when it is dry, and then quickly mature, mate and lay eggs when rain falls.
- Many birds and rodent species only reproduce during or after winter rain, which encourages plant growth.
- Some desert rodents, such as the African gerbil, feed on dry seeds and have metabolisms (body processes), which can conserve and recycle water.
- Some desert mammals, most notably camels, can survive prolonged dehydration by storing water within fatty parts of their bodies (the humps in the case of camels).
- Most desert mammals and reptiles are nocturnal and remain in the shade during the day.

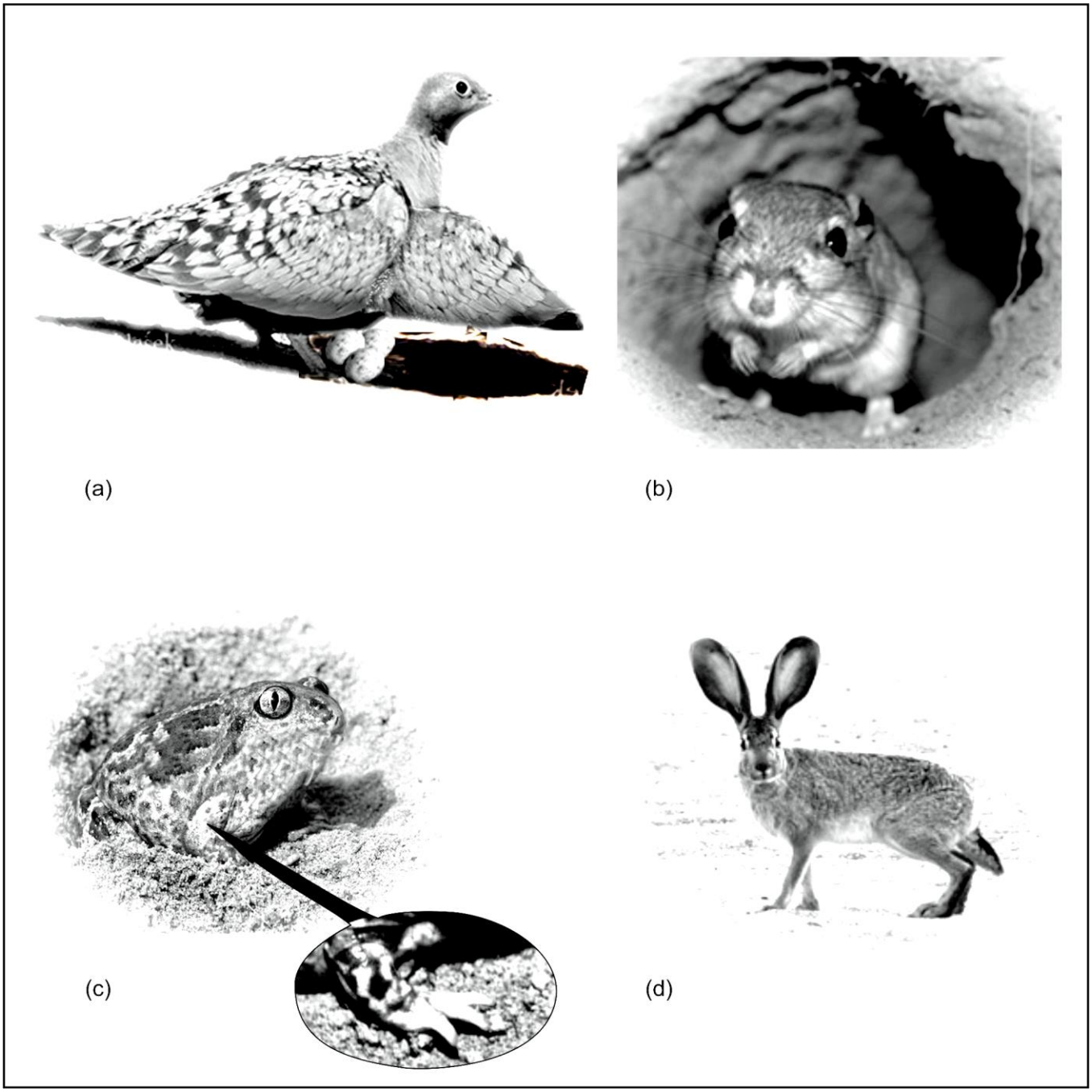


Figure 8.9: Some forms of adaptation of desert animals to the rigours of the environment:

(a) The ground-nesting sandgrouse shades its eggs during the hottest hours of the day and reduces the radiation load by erecting the mantle feathers. It also faces into the wind and raises itself above the nest, thereby facilitating convective cooling of the shaded eggs,

(b) The kangaroo rat burrows, thereby sheltering from predators, radiation and desiccation,

(c) Using its strong feet, which have a horny projection, the spadefoot toad of the Sonoran Desert can escape to depths as great as 90 cm below the surface during unfavourable climatic conditions,

(d) The enormous ears of the jack rabbit assist the animal in offloading excessive body heat.

TEMPERATE FORESTS

Temperate forests comprise of temperate rainforest, temperate deciduous forest, temperate grasslands, and temperate scrubland.

TEMPERATE RAINFORESTS

Dense forests in the sub-tropical or warm temperate mid-latitudes on the western coasts of continents, where rainfall is abundant and fairly well-distributed, are called as temperate rain forests. The temperate rain forests occur between 23° and 35° in both the Northern and Southern Hemispheres; in the north-western of USA along the Pacific coast, in southern China and southern Japan, in south-eastern Australia, in New Zealand, in southern Brazil, in South Africa and in Chile. The climate in these areas is cool and maritime, without great variations in temperature. The absence of a distinct cold season, and the presence of abundant summer rain along with much cloudiness and fog, resulted in the formation of these forests. Rainfall occurs almost throughout the year, like in the tropical rain forests; but at certain times of the year, rain is condensed into fog, formed by moisture brought in from the sea by winds. Rainfall may vary between 38 cm to 100 cm, most of which occurring in winter, which allows the resting plants to begin vigorous growth as soon as the temperatures begin to rise. However, during the long dry summer, the plants have to withstand drought-like conditions. Despite a great richness in species, the temperate rain forests have less luxuriant growth than the tropical rain forests, chiefly because of the relatively lower temperatures.

Most of the areas with "Mediterranean" type climate were covered with broad-leaved evergreen forests in the past. They are now covered predominantly with an evergreen sclerophyllous vegetation. The long dry heat of the summer in these biomes requires the plants to develop xerophytic features. The resultant vegetation is described as sclerophyllous, due to their hard, tough and evergreen leaves. The chief distinctive feature of such climates is the seasonal alternation of warm, moist winters and hot, dry summers, with rather indistinct autumn and spring seasons.

These forests contain mixed vegetation, containing broad-leaved evergreens, broad-leaved deciduous trees and conifers. In some areas conifers are dominant. Vegetation may also show some features of the low-latitude tropical rain forests, as they merge into each other in some areas. However, in the temperate rain forests, the tree canopy is less continuous, trunk buttresses are absent, lianas are less common, and there is a dense undergrowth of palms, shrubs, ferns and bamboos. Some of the tallest trees in the world, like the **Mountain ash** in Australia (more than 90 metres), and the **Redwood** trees in North America (more than 100 metres), are found in the temperate rain forests. Epiphyte diversity is high in the temperate rain forests, with a number of mosses, lichens and some ferns. Since these cool forests are unaffected by fire, they contain some of the world's largest and oldest trees. The low temperatures also make decomposition on the forest floor a very slow process.

Trees, typically, have broad, evergreen and hard leaves, which are, however, relatively small. The evergreen forests have dense, shrubby vegetation, 1-3 metres in height with deep-penetrating roots. The predominant trees in these biomes are evergreen oaks, like the helm oak and the kermes oak. Other trees found in these forests include wild olive, fig, cork oak and stands of pine. Groves of oleander are common near streams or where the soils are moist. There are scrub woodlands found in many areas that suffered deforestation of the original evergreen forests, such as in Cyprus. These scrubs are dominated by both evergreen and deciduous shrubs, like cistus, gorse, broom, rosemary and laurel.

Plants in the Mediterranean biomes show the following characteristic features:

(i) Typically sclerophyllous (hard leaved) vegetation, with small, durable leaves.

(ii) These are widely spaced and are of moderate height. There are evergreen shrubs between the trees.

(iii) Xerophytic characters are shown by the plants to tide over the summer droughts.

(iv) Thick bark, along with small, hard and leathery leaves minimize moisture loss.

(v) Leaves may, further, be covered with wax or hairs (e.g., olive) to limit water loss.

(vi) Fruits have thick, light-coloured skins.

(vii) Trees and shrubs have deep-penetrating roots to tap underground water sources.

(viii) Many shrubs flower and seed well before the summer drought sets in. For example, tulip, lily and narcissus tend to die down in summer.

(ix) The period of active growth for most plants is the warm, wet winter or spring.

(x) Forest fires are rather frequent, and most plants have either fire-resistant seeds or root crowns that resprout soon after a fire.

The broad-leaved evergreen forests are believed to be the climatic climax vegetation of much of the Mediterranean region.

TEMPERATE DECIDUOUS FORESTS

These broad-leaved deciduous forests (also called as deciduous summer forests or summer–green deciduous forests) occur throughout temperate latitudes whereever there is sufficient water to support the growth of tall trees. These forests are typically found in continental climates with a high degree of seasonality, ranging from cold, sub-zero winter with frost and snow, to warm, mild and, often, net summers. They can be found in many regions of Europe, eastern Asia and the Americas. Most of the deciduous forests of Europe and Asia have disappeared, as they were cleared for human settlement and agriculture. They are rather poorly developed in the southern Hemisphere due to the milder winter temperatures of moderate latitudes.

The vegetation in the temperate deciduous forests is dominated by trees of deciduous habit, which shed their leaves before winter. Thus, the trees are dormant and leafless in the cold and frosty winter. The lowering of temperatures in winter causes a physiological drought since the reduction in soil temperature limits the ability of roots to absorb water. Absolute physiological drought sets in when the soil is frozen, and the shedding of leaves helps the trees to conserve moisture, by minimizing transpirational water loss. Thus, the deciduous habit enables the plants to survive the frosty period without much loss of moisture. Leaves and buds begin to develop as soon as the temperature rises above 6°C. This is followed by blossoming, flowering and bud-bursting. The appearance of these forests in the winter and summer presents a wide contrast, from sombre and lifeless in winter to lively and colourful in summer.

The trees in the temperate deciduous forests are dominated by oak, maple, beech, birch, walnut and hickory, with a subcanopy layer of smaller trees and shrubs. Herbaceous plants complete their growth and flower early in spring before the trees are fully leafed and blocking of sunlight. The height and density of the canopy and the composition of the understory vary greatly depending on local conditions.

TEMPERATE GRASSLAND AND SHRUBLAND

Temperate grasslands develop in areas of moderately dry and continental climate, with an annual rainfall of between 25 cm and 85 cm. They are also characterized by hot and wet summers and cold winters. They are found around the world, in both hemispheres, but more pronounced in the north due to its more marked continental climate. The Northern Hemisphere grasslands are the Eurasian ***Steppes***and the central North American prairie, while the main Southern Hemisphere grasslands are the ***Pampas***of Argentina, the ***Veldt*** of South Africa and the ***Downs*** of south-east Australia. In general, the steppes have short grasses whereas the prairy, which are more humid, have tall grass.

The general features of grassland vegetation are:

(i) Vegetation is dominated by perennial grasses, which grow to over 2 metres in the moister parts and to less than 20 cm in the more arid areas.

(ii) The grass grows in tufts, along with broad-leaved perennial herbs and other plants. The non-grass herbaceous plants are referred to as *forbs*.

(iii) The smaller broad-leaved plants flower early in the growing season, before the growing grasses reach their maximum height. On the contrary, the large broad-leaved plants flower toward the end of the growing season after the grasses have began to die down.

(iv) The rainfall is insufficient for tree growth, although trees may occur along river banks.

(v) The growing season for most of the vegetation (especially the grasses) is summer, when light rains are frequent.

(vi) Grasses die down in winter, either due to drought-like conditions in the warm temperates or due to winter cold in the cool temperate areas. Because most of the grasses (above the ground) die and decompose each year, organic matter accumulates to produce a deep fertile soil.

(vii) Fire has a dominant influence on grasslands with the result that most species have fire-resistant underground stems, called rhizomes, from which shoots resprout. The dry condition is the main cause of fires, which burn the plants and grasses above the ground, but the fires do not harm the roots from which new life can spring. Seeds are also usually fire-resistant.

Animal life in many of the grasslands is remarkably similar. Most of the fauna can be found within the strata of vegetation, such as the roots, ground layer, and herb cover. Insects, earthworms and ants are abundantly found at various times of the year. Mammals, especially herbivorous ones, are the most conspicuous animals of these grasslands. Grazing animals, like the wild ass, saiga antelope, bison, etc. are commonly seen. North American prairie are rich in these ungulates. Kangaroos are the grazing equivalents of ungulates in the Australian grassland. However, ungulates are absent in the South American Pampas; instead large rodents living in herds graze these grasslands. Grassland animals, in general, have strong hind legs, which aid in locomotion by hopping and leaping. They are also quite speedy, like the antelopes and the cheetah. The lack of trees has resulted in fewer birds, as they have to nest on the ground. Even eagles are known to have ground nests in grasslands.

Steppe: These temperate grasslands, found in the continental interiors of Asia and Europe, have short grasses of less than 30 cm height. Steppes are found in dry areas that have hot summers and cold winters. The annual rainfall range from 25 to 50 cm, which is less than on a prairie, but more than in a desert. The Eurasian Steppes extend from south-western Russia to the central Asian parts of Kazakhstan. In spring, the steppe has many colourful flowers, such as crocuses, hyacinths, irises, pasque flowers, and valerians. Steppe fauna include a large number of small rodents, such as marmots, ground squirrels, susliks and lemmings, birds, such as demoiselle cranes, great bustards and plovers, and snakes like the Orsini's vipers and whip snakes. Most of the original steppe, particularly the European part has how been replaced by cultivation, since their rich and fertile chernozem and chestnut-brown soils are well-suited to large scale cereal-growing.

Prairies: These humid grasslands of interior central and western North America extend from 53°N in Canada to 32°N in Texas, USA. They have a thick cover of tall grass, the height being determined by the rainfall gradient. There may be patches of forests within these grasslands. The dominant grass species are big bluestem, switchgrass, needlegrass, wheatgrass and June grass.

Pampas: The Argentinian temperate grasslands are the prairy of South America. They cover an area of about 1.3 million km^2, spaning over Argentina and Uruguay, with little overlap into parts of Brazil. Most of the Pampas is a level, monotonous plain, covered with species, such as feather grass and melic, which grow in individual tussocks.

Veld (Veldt): These South African prairie are found along the eastern parts of the South African Plateau. The western part of the plateau has the so-called "sand veld" vegetation, which shows patches of treeless grassland. The grassland towards the north of the typical veld, called as the 'bush veld', are increasingly dotted with low trees and shrubs, giving it a savanna-like appearance. The dominant grass species differ in different parts of the veld, and include the red grass, wire grass, etc.

TEMPERATE SHRUBLAND

This is sometimes described as a sub-type of the temperate evergreen forest biome because there is an overlapping of these two types of forests. Shrublands occur in areas where the 'Mediterranean' type of climate is more severe than in the typical temperate evergreen forests. Shrublands are also formed in areas where the evergreen forests have been destroyed or degenerated. Temperate shrubland areas receive 30 to 80 cm of rainfall, with no rain during the summer lasting upto 4 months. The mean summer temperature ranges between 20 and 25°C, and the coldest temperature is about 10°C with only sporadic frosts. Like the temperate evergreens, the temperate shrublands are found around the shores of the Mediterranean sea, in southern California, parts of Chile, Cape of Good Hope and south-western Australia. These shrublands are known in different areas by different names:

Chaparral – Californian and other American scrublands

Maquis – French name for the shrublands in the Mediterranean basin

Macchia – Italian name for the same

Mattoral – Spanish term for the same

Heathland – Ireland, England and Denmark
Mallee – Australian scrubland

Vegetation in the above regions is similar, although individual plant species may vary. The shrubs are 1 to 5 metres high, with small, thick, drought-resistant leaves. The Californian ***chaparral*** is typically treeless, with a floristically rich, thick shrubby growth. Some areas in the chaparral may contain some trees, which are only upto 12 m tall and are twisted and gnarled, like the evergreen blue oak and the bush oaks. Most of the chaparral shrubs are fire-resistant. In the Mediterranean ***maquis***, the scrublands form impenetrable thickets of dense, tangled shrubs, with scattered, dwarfed and twisted trees. The most common shrubs in the maquis are myrtle, rosemary, lavender, heather, vines and broom. Thin, poor and dry soils especially in limestone areas of the Mediterranean basin have a more degenerated form of scrub woodland called as ***garigue***. It has low-growing, patchy and highly sclerophyllous vegetation consisting of many aromatic plants. The typical plants of the garigue are heathers, sage, lavender and thyme. The Australian ***mallee*** resembles the northern hemisphere shrublands, but with different species of plants. In the south-west of Western Australia, there are forests of tall eucalyptus, tuart, jarrah and karri trees, with a prolific undergrowth of hard-leaved shrubs. Different species of eucalyptus dominate the mallee species.

The temperate shrublands, such as the *chaparral*, *maquis* and *mallee*, are often affected by fires, which burn off the stems above the ground. Regrowth occurs from the root systems that survive the fire and from burried seeds.

BOREAL FOREST (TAIGA)

This is a characteristic high-latitude biome in the Northern Hemisphere. Also called as the northern coniferous forests, they stretch in a broad belt centred at about 50°N in North America and about 60°N in Europe and Asia. The boreal forests extend from north-eastern Europe across Russia to the Pacific Ocean and right across North America from Alaska to Newfoundland. The boreal forests merge into the tundra in the north, and into deciduous forests or grassland to the south. The northernmost edge of the boreal forest, which forms a ragged border with the tundra, is referred to as 'taiga', the Russian term for 'coniferous forest'. The boreal forests exist under extremely severe cold climates, with long and cold winters. The annual mean temperature is very low and only four to five months have temperatures of 6°C or more, the lower limit for plant growth. January temperatures may be as low as –50°C to –60°C in parts like Eastern Siberia. The deeper soil layers may remain frozen year round, and the ground may be covered with snow for much of the year. Summers are short, but with long hours of daylight. Precipitation is at best moderate, ranging between 30 cm and 70 cm, and it mainly occurs in the summer. Since evaporation is low, soils remain moist throughout the growing season. Moreover, due to the slow decomposition of leaf litter and due to the formation of organic acids from the decaying needles, soils become acidic and restrict fertility. Consequently, boreal forests have low species diversity.

The vegetation in boreal forests consists of vast, dense stands of evergreen coniferous (=cone bearing) trees. On the polar margins of the biome, the trees are smaller, stunted and more widely spaced; whereas, on the Southern margin, conifers are mixed with deciduous trees.

The general features of the taiga vegetation are as follows:

(i) Vegetation consists of a few species of coniferous trees, such as pines, spruces, firs larches, cedar and hemlock. Except the larches, the other trees are evergreen and grow in vast stands of one variety. These trees are the world's main sources of commercial softwoods.

(ii) There are broad-leaved species of trees, such as poplars and birches.

(iii) The leaves that fall from the trees on the ground form the deep layer of leaf litter being partially decomposed. The decomposition is slow because of the low temperatures, waxy coating of conifer needles, and high soil acidity. This prevents most other plants from growing on the forest floor. Another reason is the frozen ground for long period in the year.The sparse undergrowth mainly comprises dwarf birch, small shrubs, mosses and lichens.

(iv) The vegetation is extremely frost-tolerant.

In order to survive the rigorous climatic conditions, the taiga vegetation has developed various adaptations. Some of these adaptations are:

(i) Compact form and conical shape, which help in shedding their burden of snow. This prevents the accumulation of snow on the tree.

(ii) Downward bending branches help in the shedding of snow.

(iii) Small needle-shaped leaves with thick cuticles to reduce water loss.

(iv) Leaves close their stomata in winter to minimize transpiration.

(v) Thick resinous bark helps to protect the woody tissues from frost.

(vi) Slender and flexible trunks can withstand strong winds. The conical shape of these trees is also useful in this regard.

(vii) Root system lies very close to the ground. The shallow roots enable the trees to procure water as soon as the frozen surface begins to thaw out.

(viii) Due to their evergreen habit, they can begin photosynthesis, as soon as the weather becomes warm and the days brighter.

(ix) Seeding by cones instead of fruits prevents quick rotting.

Animals living in the boreal forests also show a variety of adaptive features; some of them resembling adaptations by the tundra fauna. The harsh winters often force them to migrate to lower latitudes. Another common response is hibernation, where the animal goes into a long spell of dormancy to tide over the cold period. Many have adapted to the conifers, as they feed on the cones. Like in the tundra, many animals show seasonal periodicity and their populations have cyclical oscillations in their numbers. The more conspicuous animals in the taiga biome include deer, elk, moose, bear, caribou, lynx, wolves, etc.

TUNDRA

The treeless cold desert biome found sandwiched between the boreal forest and the polar ice caps and also at high elevation on tall mountains is called the tundra. The word 'tundra' has its origins in the Finnish word 'tunturia', meaning 'treeless plains'. The tundra encircle the top part of the world and extends all around the North Pole. Usually two kinds of tundras are identified; the Arctic tundra and the alpine tundra. The Arctic tundras are located near the Arctic Ocean as an almost continuous, circumpolar expanse of treeless land. In North America, the tundra extends as a wide stretch from the Bering Strait, through Alaska and northern Canada to Greenland. The circum-Arctic tundra in Eurasia stretches from northern Scandinavia to Eastern Siberia, almost reaching upto the Bering Strait. Alpine tundras are located on the high mountains in the temperate and even tropical climate zones; such as the Rocky Mountains of North America.

Tundras present the harshest conditions for life. The climate is polar, with extremely cold and dry winters, and very short summers. During the winter, the tundra is frost-covered for at least 7 months. Precipitation is normally less than 60 cm, sometimes even less than in the hot deserts, and most of it is in the form of snow. The short summers have temperatures ranging between 3°C to 12°C. However, the days are long, which compensate for the low angle of the sun. The soil surface thaws out in summer. However, the soils are permanently frozen from about 30 to 150 cm below the surface of the ground. This permanently frozen, impermeable layer of soil that lies under the top surface of the ground is called the *permafrost*. It prevents water from draining away, and as a result, the soil stays cold and wet throughout the growing period in the summer.

Soils also tend to be acidic due to the high organic matter content and low rates of decomposition. They are also very poor in nutrients. The annual freezing and thawing gradually turns the soil over and sorts the soil particles by size, thereby forcing the large stones to the surface. Thus, the climatic conditions are very hostile and the soils are unstable to support much life.

The tundra vegetation comprises low herbaceous perennial plants covering a treeless landscape in a single dense stratum of only a few centimetres in height. The productivity of this biome is extremely low, usually less than 1 g of dry matter produced per day per m^2. Since the area falls in the midnight sun latitudes, the growing season is very

short, rarely exceeding 6-10 weeks. For many plants the growing period is less than 50 days. Annual plants are, therefore, rare.

The chief features of the tundra vegetation are:

(i) Adapted to extremely cold climates. Only cold-loving plants, the **cryophytes**, survive in the tundras. These are mainly monocotyledons, like grasses.

(ii) Adapted to lack of adequate moisture, as water is in the form of unusable ice. Consequently, the vegetation generally shows xerophytic characters, aimed at reducing transpiration, such as short stems, small leathery leaves with hairs or with rolled-up edges, etc.

(iii) Adapted to the short growing periods of the tundra biome. Successful species have a physiological system adapted to fully make use of available solar energy at lower temperatures during the short growing period of 6-10 weeks.

(iv) The advent of summer is marked by bursts of plant growth and flowering, which turn the landscape into a lively, spectacular, open expanse. The landscape is also dotted with puddles, bogs and shallow-lakes, formed by the thawing of surface ice in the summer. Productivity remains high for a few weeks.

(v) Their dwarfish nature and prostrate (horizontal) growth along the surface enable the tundra plants to withstand the strong icy winds characteristic of the region. Low heights are also necessitated by the shallow root system, which cannot support vertical structures. The roots grow laterally along and just below the surface. This enables them to avoid the permafrost below, and at the same time, take up the nutrients available close to the surface.

The tundra vegetation has the following characteristics:

(i) The typical vegetation cover consists of mosses, lichens and coarse meadow grasses. In the better-drained sunnier places, there are herbs and flowering plants (poppy, anemone and saxifrage) as well as berry-bearing plants like the crowberry and bilberry.

(ii) Trees are generally absent, except for dwarf willows, alders and birches, which are found in sheltered hollows and on south-facing slopes, particularly near the coniferous forest margins of the Tundra zone.

(iii) As the tundra regions lie in the cold latitudes of the midnight sun, the growing season is very short, rarely more than two to three months. This short summer season with its long hours of daylight is warm enough to thaw the top layers of soil and encourages continuous plant growth.

(iv) In the flat low lying areas the thawing of the topsoil leads to waterlogged conditions on the ground. Here only mosses, sedges and lichens are to be found.

(v) The plants of the tundra have a small vertical development for the following reasons:

(a) The roots, which give support to plants as well as supplying nutrients, are shallow since the lower soil layers are permanently frozen. Most tundra plants therefore have roots, which extend laterally near the surface.

(b) Strong, cold dry winds are common. Plants growing to any considerable height would thus be vulnerable to uprooting, because of their shallow root systems. In addition they would suffer excessive losses of moisture because of increased transpiration.

(c) Most of the plants are dwarf, prostrate, woody shrubs that grow low to the ground for protection from winter snow. Such plants that grow low and close to the ground surface are called ***chamaephytes***.

(d) Trees or tall plants cannot survive in the cold and windy tundra because they would lose too much of their heat. Most of the growth of the plants are limited to 6-8 weeks of summer, when the sun shines almost around the clock.

Table 8.2: Plant adaptations in the Polar Regions

Adaptation	Effect
Prostrate shrub	Insulation between snow, protected from icy winds
Annuals rare	Growing season too short for full cycle

Herbaceous perennials common	Large underground root structure; storage of food over winter
Reproduction often by rhizomes, bulbs or layering	Avoids reliance on completing flower to seed cycle
Pre-formed flower buds	Maximises time for seed production
Growth at low positive temperatures	Maximises length of growing season
Optimum photosynthesis rate at lower temperatures than most plants	Maximises length of growing season
Frost resistance	True of flowers, fruits and seeds
Longevity	Suitable for 'opportunist' life style; e.g., lichens may live for several thousand years
Drought resistance	Suitable for rock surfaces or arid climates

Animal life in the tundra is also influenced or, rather, limited by the severe cold and shortage of radiant energy. Most of these animals have to resort to winter migration, hibernation or cold adaptations, in order to survive in these hostile conditions. Tundra fauna are most visible from spring to autumn. Along with the plants, which appear in the spring and early summer, a variety of insects, birds and mammals appear to come to life all of a sudden. There are grazing animals such as the caribou, reindeer and musk oxen, which are, in turn, preyed upon by wolves and other carnivores. Other common animals include Arctic foxes and hares, grizzly bears, lemmings, polar bears and ptarmigans. Along the coastlines, seals and walruses are found commonly. Numerous birds, like water fowls, geese, shore birds, etc. are seen during the summer period. They come to nest, lay eggs and raise their young in summer. The 24-hour daylength helps in prolonged round the clock food gathering. In the autumn, caribou, reindeer, and most birds migrate further south to their winter feeding grounds. The herbivores need to be migratory because the productivity of the vegetation being low, they have to cover large areas for foraging.

Animals, which remain in the tundra throughout the winter, show many adaptations, such as:

(i) Most of the animals live in burrows like the lemmings.
(ii) They have a thick layer of fat underneath their skin (sub-cutaneous fat). This provides them with effective insulation from heat loss.
(iii) Heat loss is further reduced by vertically positioned hairs on the body.
(iv) Blood circulation is restricted to the deeper layers of the body, in order to reduce heat loss across the skin.
(v) Many of them use camouflage by adopting body colours similar to the background (e.g.,a**rctic ermine, snowy owl, polar bear**, etc).

The tundra community is highly fragile and variable. Species diversity is low and the low growth rate further exposes the community to wide fluctuations. Human interference in the Arctic tundra has been minimal, especially because very few people live in the tundra, except for the Inuits and some Eskimos. However, the Arctic tundra is rich in natural resources, as large deposits of coal, oil, natural gas, iron ore, lead and zinc are located there. Their exploitation by humans pose a threat to the tundra environment.

Table 8.3: Animal responses to extreme polar climates in the Arctic.

Stress conditions	Response
Severe climate	Low number of species
	Low mean densities
Low temperature	High quality fur insulation Increased metabolic rates
Snow	Life below snow patch for smaller animals Large herbivores favour soft/thin snow
Short summer	Birds migrate Breeding cycle compressed Large clutch/litter size

Unlike in the Arctic, the Antarctic has little tundra vegetation, since almost the entire Antarctic continent is devoid of vegetation. Two species of flowering plants are known to exist in the Grahamland peninsula, and a few snow-free islands have some mosses and lichens. But they do not cover large areas.

The Tibetan antelope: Chiru

The Tibetan antelope or chiru is native to the Tibetan plateau including China's Tibet Autonomous Region, Qinghai province, and Xinjiang Autonomous Region; and in Ladakh, Jammu and Kashmir region of India and Pakistan.Chiru's can be found at elevations from 3250 - 5500 m (10,660 - 18,000 ft).

Chirus live on the high mountain steppes and semi-desert areas of the Tibetan plateau such as Kekexili, where they feed on various forb and grass species.

Chiru has a lot of characteristics that are unique to it

- The chiru is a remarkable runner. Despite the thin atmosphere on the high plateau, it can run as fast as 80 km/h (50 mi/h).
- The chiru produces the finest wool in the world -- a single woven shawl sells for up to $15,000. The demand for their pelts also puts the chiru in danger of being hunted to extinction.

Table 8.4: Summary of Land Biomes

Biome	Climate	Dominant plants	Examples of common animals
Tropical Rainforest	Warm and wet all year	Broad–leaf evergreen trees, some palms and tree ferns, climbing vines	Amphibians, bats, Insects, colourful birds (such as macaws), monkeys, sloth, snakes
Scrub Forest	Rainy, mild winters; hot, dry summer; fires common	Low shrubs with hard, glossy leaves, such as bay, scrub oak, and strawberry tree; also shrubs with leaves containing aromatic oils, such as cistus	Coyote and jackal, rabbit, many species of lizards
Savanna	Long dry season	Grasses and scattered clumps of trees, such as acacia and baobab trees	Antelopes, cheetah, giraffe, jackal, lion, zebra
Desert	Extremely dry	Cacti and other fleshy plants, sparse grasses, small–leaved shrubs	Small rodents such as jerboa, kangaroo rat, and wood rat; lizards and snakes; scorpions
Temperate Evergreen Forest	Cool, moist middle and upper mountain slopes; coastal area with mild winters and heavy rainfall	Evergreen trees, including cedar, hemlock, pine, and redwood	Bighorn sheep, grizzly bear, mountain beaver
Temperate Deciduous Forest	Cold winters, warm moist summers	Broad leaf deciduous trees, such as elm, maple, and oak	Deer, dormouse, European badger, hedgehog, raccoon, squirrels, many small insect–eating birds
Temperate Grassland	Temperate, subhumid	Grasses and other herbaceous plants	Buffalo, bustard, badger, prairie dog, saiga antelope
Boreal Forest (Taiga)	Cold winters, short growing season	Coniferous evergreen trees: firs, larches, pines and spruces	Bear, elk and moose, lynx, wolf, ducks and divers
Tundra	Extremely cold, dry; permanently frozen subsoil	Lichens, low shrubs, sedges	Arctic fox, caribou, lemming, polar bear, snowy owl, wolves, many migratory wading birds

ALPINE TUNDRA

These are tundra like vegetation on mountains throughout the world at elevations too cold for trees to grow. Unlike the Arctic tundra, these high altitude areas have no permafrost. Moreover, their soils are well drained. Alpine tundra generally has warmer and longer growing seasons, higher precipitation, less severe winter, greater productivity and higher species diversity than the Arctic tundras. In general, the alpine tundras are dotted with rock-strewn slopes, bogs and alpine meadows covered predominantly with hair grass and shrubby thickets. Although there are similarities between the Arctic and Alpine tundras, only about one-fifth of the plant species are similar. Moreover, they do not form continuous expanses like the Arctic tundra, instead, they occur as island-like and relatively limited areas in various latitudes. The characteristic animal species of Alpine tundra include pikas, mountain goat, mountain sheep, marmot and elk. A wide variety of insects, such as, springtails, grasshoppers, butterflies and beetles are also very common. The main Alpine tundra in the temperate zone are the Rocky Mountain tundra and the Appalachian Mountains of North America, the Alps of Europe and the Tibetan plateau. Those in the tropical regions include the high mountains in Central America, South America, Africa, Borneo, New Guinea, Java, Sumatra and India.

AQUATIC BIOMES

Terrestrial biomes, described above, are primarily based on the dominant vegetation in a particular geographical region. However, such a classification of the aquatic habitat is not possible because of the absence of a sessile vegetation with a characteristic structure. In the aquatic habitat, there is a third dimension, namely, the water column, where most of the life forms exist either drifting passively or swimming actively. Therefore, the classification of the aquatic habitat is based on physical characteristics, such as differences in salinity, depth, water movement, etc. Here again, the physical factors, which contribute most to the geographical patterns in distribution, differ in the terrestrial and aquatic environments.

In the land ecosystems, temperature and humidity are the principal factors. However, due to the high specific heat of water, temperature varies less on a daily, seasonal or latitudinal basis in the aquatic habitats. Instead, salinity, pressure, light and tidal rhythms play more important roles in determining the distribution of aquatic organisms. The most commonly used factor is salinity, and the aquatic habitats could be classified on the basis of their salinity into:

(i) Fresh water biomes, and

(ii) Marine biomes, with a transitional community in between namely, the estuarine community. The salt concentration of oceans is about 35 parts per thousand (‰), while even the most salty fresh water bodies have salinities less than 0.5‰.

MARINE BIOMES

Marine biomes span right around the globe and form a vast expanse of water that provides the habitat for a wide array of aquatic organisms. A unique characteristic of the marine biomes is that it is essentially continuous. Various patterns of classifying marine biomes can be found in literature. A commonly adopted classification divides the oceans into nine biogeographic regions on the basis of **climate conditions**. These regions are:

(i) Arctic region

(ii) Subarctic region

(iii) Northern temperate region

(iv) Northern subtropical region

(v) Tropical region

(vi) Southern subtropical region

(vii) Southern temperate region

(viii) Subantarctic region, and

(ix) Antarctic region

Another way of classifying the various marine regions is on the basis of their **physical and structural characteristics**. Consequently, the marine biomes can be divided into:

(i) Marine rocky shore
(ii) Marine sandy beach
(iii) Marine mud flat
(iv) Temperate salt marsh
(v) Mangrove swamp
(vi) Coral reef
(vii) Deep ocean benthos
(viii) Continental shelf benthos

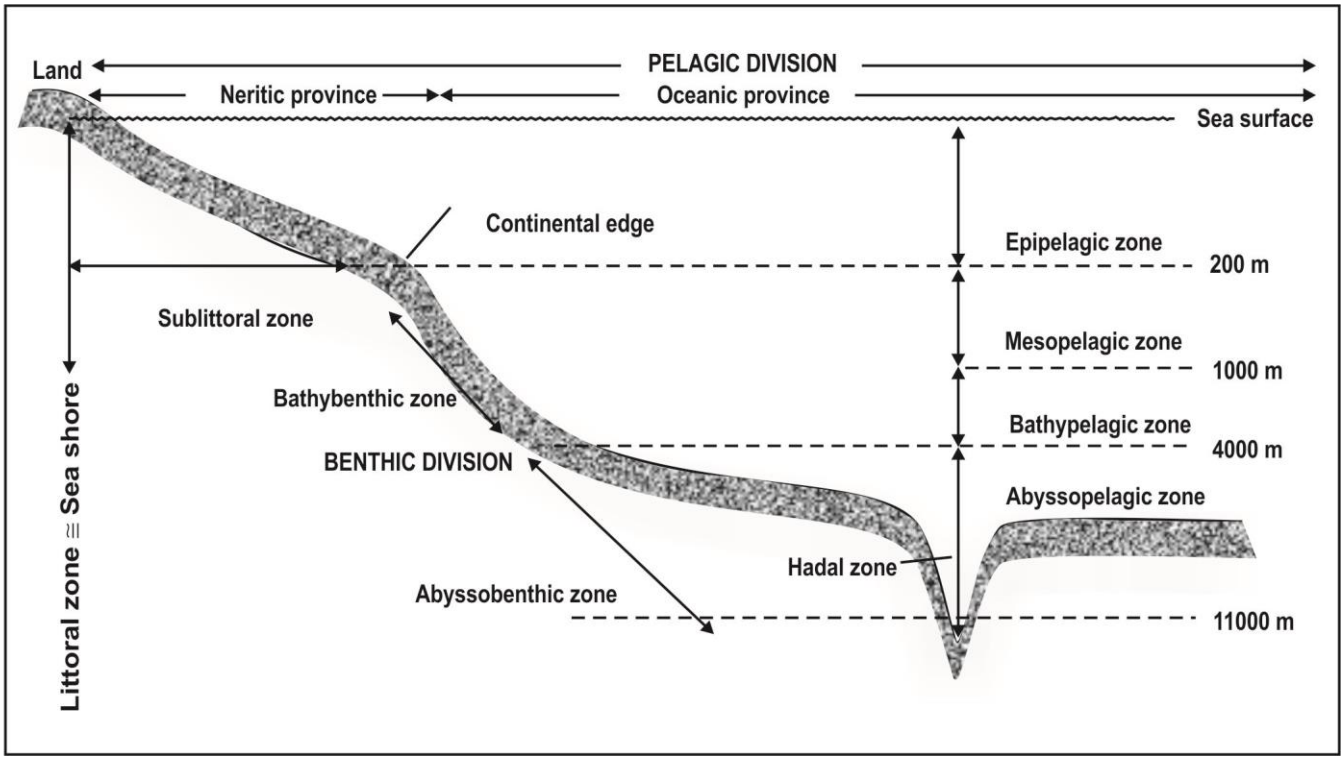


Figure 8.10: Main Divisions of Marine Environment

All these regions show both vertical and horizontal stratification into distinct zones, which support characteristic communities. These zones are primarily based on water depth, light availability and relationships between organisms and substrates. Vertically, the ocean is divided into two main layers, the **pelagic region**, which contains the whole body of water, and the **benthic region**, that makes up the ocean bottom. The pelagic region itself is composed of two vertical layers.

(i) **Photic zone (Euphotic zone):** This is the layer that has a gradient of available light. Since sunlight is absorbed by water with increasing depth, the photic zone has its boundary at depths, which vary in different areas. For instance, in coastal waters, the photic zone rarely penetrates more than 30m from the surface, whereas in the open oceans the photic zones may extend to as low as 200m. This light zone is very crucial because all photosynthetic activity in the oceans takes place here. Thus, all the organic energy, required to sustain the entire marine life, is essentially produced in the shallow photic zone.

(ii) **Aphotic zone**: The deep layer below the photic layer, where darkness prevails is called the aphotic (= without light) zone. The exact boundary between the photic and aphotic zones is not very distinct, since the absorption of light is gradual, but it is usually taken as the region where light penetration is reduced to between 1% and 10% of the incident sunlight.

Organisms living in the aphotic zone obtain their energy by consuming the food produced by organisms in the photic zone. Localized areas may also have chemosynthetic bacteria producing energy from hydrogen sulfide emanating from hot springs on the ocean floor, and these bacteria may form the base of a local food chain. The aphotic zone has very low temperature and high pressure, and may lie between 100-700 m and 2000-4000 m below the surface.

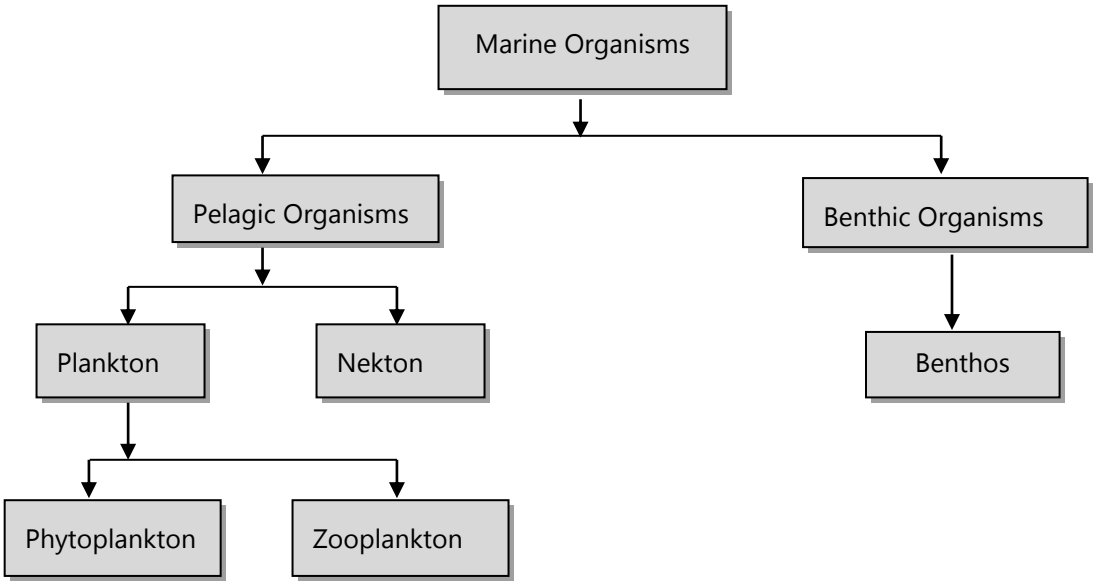
The pelagic zone is horizontally divided into the **neritic** and **oceanic provinces**. Water that overlies the continental shelf constitutes the neritic or sublittoral province, while water over the major plains of the oceans makes up the oceanic province.

The ocean bottom or bed, called the **benthic region**, is divided into three zones, namely, the **bathyal zone**, the **abyssal zone** and the **hadal zone**. The **bathyal zone** covers the continental shelf, and is the marine equivalent of mountain sides. It is a highly varied relief at the edges of a continental shelf, where the waters rapidly drop away to

great ocean depths. The **abyssal zone** constitutes most of the ocean, covering vast areas with depths ranging from 2000 m to 6000 m. **Hadal zone** is the benthic zone or sea bed of oceanic trenches between 6000 m and 10,000 m.

Horizontally, the marine communities are divided on the basis of the depth and configuration of the ocean bottom. The shallowest zone, like the margins of lakes, or where the sea meets the shore, is called the **littoral zone** or the **intertidal zone**. It is actually an ecotone between the land and the oceans, and has characteristic organisms. Further into the ocean, and constituting the waters over the continental shelves in the neritic pelagic zone, is the **sublittoral** or **neritic zone**. Beyond the sublittoral zone is the body of water that constitutes the oceanic province mentioned earlier.

Living organisms in the marine biomes are also identified on the basis of their association with the vertical layers of the ocean. Generally, marine organisms are divided into two types, **pelagic** and **benthic**. Pelagic organisms live in the water column or in the open water, whereas the benthic organisms, called **benthos**, are associated with the substratum or surface.



Pelagic Organisms: Two types of pelagic organisms can be identified, namely, **plankton** and **nekton**.

Plankton consists of microscopic organisms that float in the water column. They could be either photosynthetic plants, **phytoplankton**, like diatoms, or tiny animals, **zooplankton**, like small crustaceans and invertebrate larvae. The zooplankton may be either herbivorous, feeding on the phytoplankton (e.g., copepods, krill, etc.), or carnivorous, feeding on the herbivorous zooplankton (e.g., larvae of comb jellies, and arrow worms). The **phytoplanktons** play a very significant role that can be understood by an example. If phytoplankton of an ocean is completely destroyed for some reason then the ocean as a carbon sink would be adversely affected and the food chains in the ocean would be altered.

The nekton comprises the actively swimming animals, including fishes, whales and some large invertebrates. Nekton occupy the higher trophic levels in the marine food chain, as they derive their energy by feeding on zooplankton.

Benthic communities: They show wide variations depending on the nature of the substrate with which they are associated with. Rocky or hard sea bottoms are predominated by epiflora or epifauna, organisms that live on the surface of the substrate. Sediment-laden sea beds have the so-called infauna, animals living within the deposits. Burrowing invertebrates living beneath the surface are found on soft sandy or muddy substrates.

Marine ecosystems can also be divided into the following zones:

Oceanic, the open part of the ocean, where animals such as whales, sharks, and tuna live;

Profundal, bottom or deep water;

Benthic, bottom substrates;

Intertidal, the area between high and low tides, estuaries, salt marshes, coral reefs, and hydrothermal vents, where chemosynthetic sulphur bacteria form the food base.

FRESHWATER BIOMES

These are widely distributed in all the continents as isolated lakes, small ponds and marshes, very often connected by long, branching rivers and streams. They show considerable variations, as they are influenced not only by the local climatic conditions and soil, but also by the surrounding terrestrial ecosystems. The biological communities of freshwater biomes are primarily determined by the physical characteristics of the environment, like in the case of land biomes. However, in aquatic biomes, the surrounding medium is water instead of air, and hence the characteristic of water plays a significant role. Two types of freshwater communities are usually recognised – **lentic** or **standing waters habitat**, and **lotic** or **running water habitat**.

(i) **Lentic Systems (standing water habitats):** They comprise mainly lakes and ponds, which are inland depressions containing standing water. Their size may vary between a few square metres, as in a small pond, and thousands of square kilometres. Their depths may very between one metre and more than 2000 metres. Lakes are mainly formed as products of glaciation, which leaves behind land depressions buried with glacial ice that eventually melts. An important feature of standing waters, especially in lakes, is the clear vertical stratification on the basis of light, temperature, nutrients and organisms. In addition to the vertical strata, horizontal zones can also be identified in a lentic system. The various zones are shown in Figure 8.11.

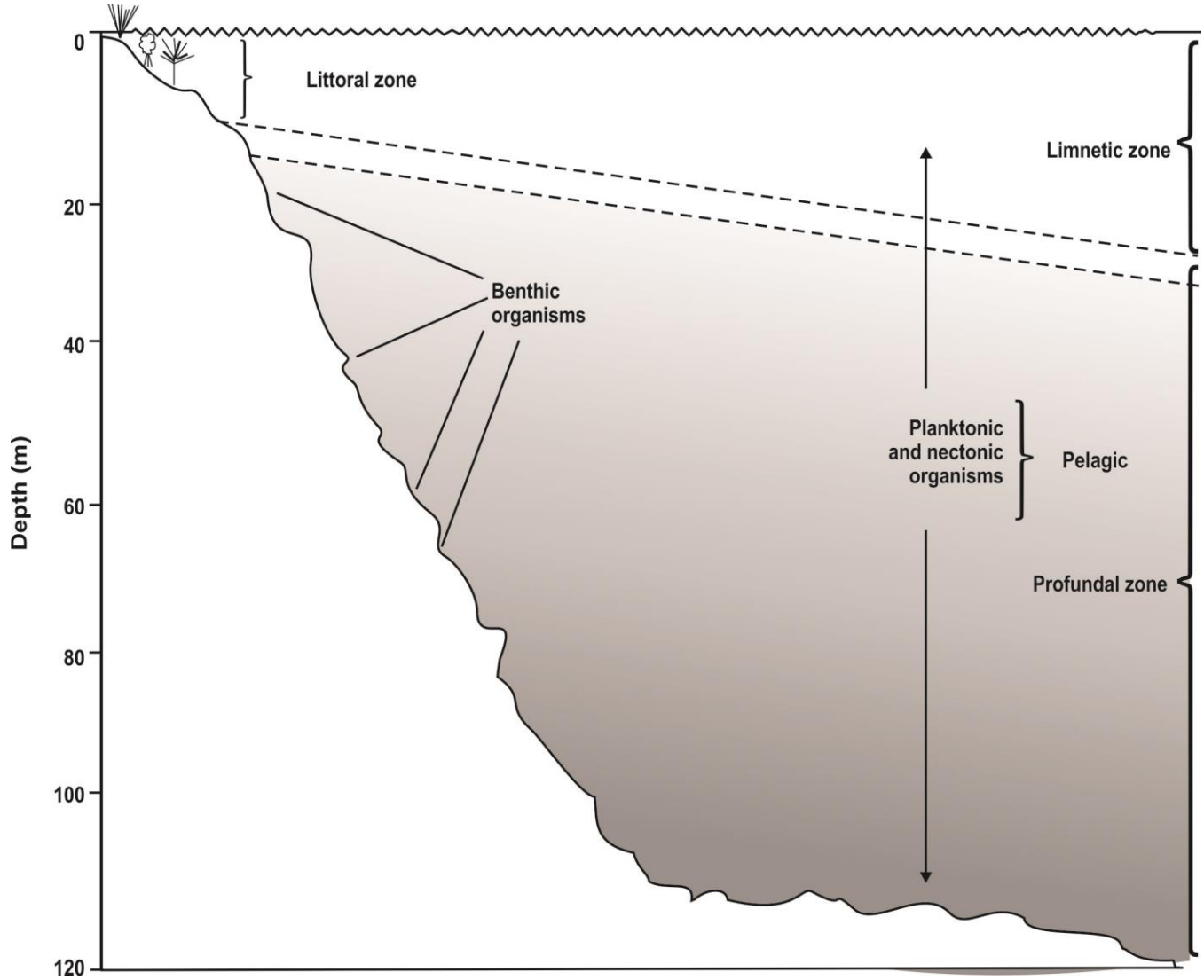


Fig.8.11: The Division of fresh water lentic communities into various zones.

(ii) The **littoral zone** or **shallow water zone:** This is the one in which light penetrates to the bottom and rooted aquatic vegetation such as water lilies and sedges are present. Beyond the shallow littoral zone is the off-shore open-water zone, called the **limnetic zone**; where light penetrates sufficiently, for photosynthesis to occur. Below the surface layer of the limnetic zone is the **profundal zone**, which being deep is beyond the depth of effective light penetration. The **benthic zone**, as in the marine biomes, is the bottom of the lake with great biological activity. The lake water is also vertically divided, on the basis of temperature gradients, into three layers;

(iii) **Epilimnion** (= upper lake): Includes the freely circulating surface waters with a small but variable temperature gradient. This warm upper layer does not easily mix with the layer below, and thus, forms a thermal barrier.

(iv) **Metalimnion** (= middle lake): This is the layer below the thermal barrier, with a steep and rapid decline in temperature of about 1°C for each one metre of depth. This temperature gradient is known as the thermocline.

(v) **Hypolimnion** (=lower lake): It is the deep cold layer above the benthic zone. It is completely cut-off from the air above.

The organisms in lentic systems can be classified into pelagic and benthic, like in marine biomes. The littoral zone, as mentioned earlier, has rooted plants. The limnetic zone has pelagic organisms, in the form of plankton and nekton. Phytoplankton, such as diatoms, desmids and algae, form the base of these aquatic food webs. Zooplankton are small animals that feed on the phytoplankton, and constitute a vital link in the food chain. Nektons, such as fishes, feed on both the phyto, as well as zooplankton, and form the higher trophic levels. The benthic organisms, called benthos, mainly comprise snails, burrowing worms and bacteria.

Many lake systems are highly productive, and in many cases productivity is limited only by the availability of inorganic nutrients, such as phosphorous. Based on their productivity, lakes, especially temperate lakes, are classified into **eutrophic** and **oligotrophic lakes**. Eutrophic lakes are rather shallow and highly productive because light penetrates to almost the bottom of the lake. In addition, vertical circulation of water that takes place with changes in the season helps in returning the mineral nutrients to the surface while carrying oxygen to the depths. Oligotrophic lakes, on the other hand, tend to be deeper, and have lower nutrient input than the eutrophic lakes. Being very deep, vertical circulation is inefficient, thereby curtailing productivity.

Lotic Systems (Running water habitats): They include rivers, streams and springs, where water is in continuous movement. The water current not only shapes the channel and determines the character of the stream, but also influences the nature of organisms that live in these systems. Lotic systems are often divided into **rapids** or **riffles** and **pools**. In the riffles, the water is well oxygenated and the bottom is free of silt, due to the velocity of the water current. Only organisms, which live on the rocky surface at the bottom and sides or those capable of swimming strongly in the current, inhabit the rapids. In contrast, pools have slowly moving water and poorly oxygenated bottoms, often laden with silt. Pools are inhabited by swimming animals in the water column and burrowing animals in the organic-rich, silty bottom substrate.

Aquatic ecosystems perform environmental functions of recycling nutrients, purifying water, recharging ground water and providing habitats for wildlife. Aquatic ecosystems are also used for human recreation, and are very important to the tourism industry, especially in coastal regions.

The health of an aquatic ecosystem is adversely affected when the ecosystem's ability to bear any stress has been exceeded. A stress on an aquatic ecosystem can be a result of physical, chemical or biological alterations of the environment.

- Physical alterations include changes in water temperature, water flow and light availability.
- Chemical alterations include rapid or slow changes in the loading rates of biostimulatory nutrients which increase algal population, microorganic activity, oxygen consuming materials, and toxins.
- Biological alterations include the introduction of exotic species either of plants or animals.
- Human populations can impose excessive stresse on aquatic ecosystems.

Wallace's Line

Boundaries between ecosystems can be abrupt if they are physically separated. In the Indonesian archipelago there is a boundary in the distribution of bird species between Borneo and Bali to the west and Celebes and Lombok to the east. Alfred Russell Wallace noted this boundary in the 1860s. It has since been called Wallace's Line and seems to mark

Eurasia's continental shelf east of Bali and Borneo; the deeper water farther east was a barrier to the spread of species during the lowered ocean levels of the Pleistocene Ice Age.

History of Evolution Concept

It has been observed that the distribution of the plant species is not uniform. In some restricted areas, there is a wide range of genetic variability. There are few such regions and generally they are small areas confined to the mountains or foothills of the tropics and subtropics. These regions having a wealth of forms, has been called *"gene or diversity centres"*. These gene or diversity centres are regions of origin as well as dispersal. From these centres, the species have migrated in different directions in course of which many recessive mutants arose. All variations from the cultivated type to a perfectly wild species are to be found in these centres. These centres are further characterized by the presence of dominant genes. It looks that the centre of gene centres was characterized by the preponderance of dominant genes and toward the peripheral regions these are replaced increasingly by recessive **alleles**. Some of the important plants of each centre are:

An allele is an alternative form of a gene (one member of a pair) that is located at a specific position on a specific chromosome. These DNA codings determine distinct traits that can be passed on from parents to offspring.

Centre of origin	Major important plants originated in the region
1. Chinese centre	136 plant species including bamboo. Tea, onion and soya bean
2. Indian centre	170 plant species including Mango, Jute, Oriental Cotton, Black pepper
3. Central Asiatic centre	43 plants species includingPea, Hemp, Garlic Almond and Apple
4. Near Eastern centre	83 plant species including Rye, Walnut Alfalfa and Persian clover
5. Mediterranean centre	84 plant species are listed including cabbage, peppermint, turnips and asparagus
6. Abyssinian centre	38 plant species are listed including Wheat and barley, sesame and castor
7. South Mexican and Central American centre	Extremely varied including Maize, squash, sisal, papaya, guava and tobacco
8. South American centre	Potato, tomato, lima bean, pumpkin, quinine tree

INDIAN CASE

India is located between 8°-38°N latitude and 68°-97°.5' E longitude. The latitudinal zonation of India makes it a tropical climate despite the northern extension touching 38°N. India also exhibits extreme variation in altitude – from sea level to heights above vegetational limits in the Himalayas (above 4500 m). Indian climate varies from monsoon tropical in south to temperate and alpine in the north-western Himalayas and extremely arid to semi-arid in the north-western plains. Floristically, India is extremely rich with about 33 percent of its botanical wealth (over 15,000 species of higher plants) being endemic. There are about 141 endemic genera distributed over 47 families (Nayar, 1980). Further, of the 4,900 endemic species, larger percentage is localised in the Himalayas (about 2,532 species) than in other regions, namely, the peninsular tract (1,788 species), and the Andaman and Nicobar Islands (185 species). It is also estimated that floristic richness is maximum in the north-eastern region, which holds about 50 percent of India's total species diversity, i.e., more than 7,000 species, and is considered as the cradle of flowering plants. Of 990 species of orchids, 700 species occur in this region.

INDIA AS GENE CENTRE

Agriculture has been practiced from a very early period and also that the ethnic make up is really diverse. Both of these have played a major role in the diversification of crop resources in the sub-continent. Thus, rich genetic diversity occurs in several crop plants and their wild progenitors. The diverse agro/eco-climate of the 'Indian Centre', which possesses about 166 species of agri-horticultural crop plants, also has a rich diversity in wild relatives of crop plants numbering about 320 species. In addition, the Indian agriculture has already been enriched by a continuous stream of introduction of new crops and their cultivars by man since the ancient times.

Table 8.5: Prominent examples of Crop Species that originated in this region are:

Cereals and millets	Rice (*Oryza sativa*), little millet (*Panicum sumatrense*), kodo millet (*Paspalum scrobiculatum*).
Legumes/pulses etc.	Black gram/urid (*Vigna mungo*), moth bean/moth (*V. aconitifolia*), pigeonpea/arhar (*Cajanus cajan*), horsegram/kulthi (*Macrotyloma uniflorum*), Mucuna utilis.
Fruits	Mango (*Mangifera indica*), banana (*Musa spp.*), jamun (*Syzygium cumini*), jack fruit/kathal (*Artocarpus heterophyllus*), Citrus group - lime and others, karonda (*Carissa congesta*), khirni (*Manilkara hexandra*), phalsa (*Grewia sub-inaequalis/G. asiatica*), bael (*Aegle marmelos*), wood apple (*Feronia limonia*), kokam (*Garcinia indica*).
Vegetables	Eggplant/brinjal (Solarium melongena), ridge gourd and smooth gourd/tori (*Luffa spp.*), round gourd/tinda (*Citrullus lanatus*), pointed gourd/parval (*Trichosanthes dioica*), tares/arbi (*Colocasia esculenta*), yams (*Dioscorea spp.*), jimi-kand (*Amorphophallus campanulatus*), kundri (*Coccinea indica*), cucumber (*Cucumis sativus*), Raphanus caudatus - mungra type.
Oilseeds	*Brassica spp.* (rai, sarson and toria types).
Spices and condiments	Turmeric (*Curcuma domestica*), ginger (*Zingiber officinale*), cardamom (*Elettaria cardamom*), Bengal cardamom (*Amomum aromaticum*), long pepper, black pepper (*Piper nigrum*), betel leaf and cinnamon/dalchini (*Cinnamomum zeylanicum*).
Other crops	Titapat/jute *(Corchorus capsularis)*, tree cotton (*Gossypium arboreum*), sugarcane (*Saccharum officinarum*), sunnhemp (*Crotalaria juncea*), bamboos, dhencha (*Sesbania sesban*) and tea (*Camellia sinensis*).

GENETIC DIVERSITY AND ITS DISTRIBUTION

The geographic areas which show large genetic diversity vary from eight to twelve in number, lie between 20° and 45° latitude north and south, and are and shared by and large by the same distribution and boundary as world's major vegetation formations/biomes/floristic zones.

The Indian gene centre is one such important region of diversity of crop plants. It has strong linkages and contiguity with the Indo-Chinese-Indonesian, Chinese-Japanese and the Central-Asian regions. Moreover, the influx of germplasm in distant past from the Mediterranean, African and tropical American regions, has built up enormous locally adapted and selected variability.

The Indian subcontinent possesses rich floristic wealth. Of this 3,000-5,000 species are of economic value, which include about 1,000 wild food plants. The diversity in plant genetic resources numbers around 166 species and the wild genepools of direct or indirect utility, around 320 species, distributed in eight phyto-geographical/agro-ecological zones. Three generalisations with respect to genetic diversity in India can be drawn.

1. **India is a primary centre** of diversity for crops, such as rice,

Important terms related to Gene Pool Concept and its Conservation

The sum totals of hereditary material, i.e., all the alleles of various genes, present in a crop species and its wild relatives are referred to as germplasm. This is also known as genetic resources or gene pool or genetic stock. Important features of plant genetic resources are:

- Genetic pool represents the entire genetic variability or diversity available in a crop species.
- Germplasm consists of land races, modern cultivars, obsolete cultivars, breeding stocks, wild forms and wild species of cultivated crops.
- Germplasm includes both cultivated and wild species and relatives of crop plants.
- Germplasm is collected from centres of diversity, gene banks, gene sanctuaries, agricultural farms, markers and seed companies.
- Germplasm may be indigenous (collected within country) or exotic (collected from oustside countries)

black gram, moth bean, pigeonpea, cucurbits like smooth gourd, ridge gourd and pointed gourd, tree cotton, *capsularis* jute, jack fruit, banana, mango, *Syzygium cumini*/jamun, large cardamom, black pepper and several minor millets and medicinal plants like *Rauvolfia serpentina* and *Saussurea lappa.*

2. **India is a secondary centre** of diversity for African crops, such as finger millet, sorghum, cowpea, cluster bean, okra, sesame, niger and safflower; tropical American types like maize, tomato, pumpkin/*Cucurbita* spp., chayote or chou chou, chillies and *Amaranthus;*

3. **India is a regional (Asiatic) diversity centre,** for crops like maize, barley, amaranth, buckwheat, prosomillet, foxtail millet, mung bean/green gram, chickpea, cucumber, bitter gourd, bottle gourd, snake gourd and Brassicae.

Geographical contiguity with the Far-East and/or the Indo-Malayan (South/South-East Asian region) belt is largely responsible for more regional diversity in mung bean, rice bean, sword bean, tomato, citrus, small cardamom, Saccharum, ginger, turmeric, tuber crops, particularly taros and yams, and bamboos.

GERMPLASM CONSERVATION

Germplasm conservation refers to protection of genetic diversity of crop plants from genetic loss and degradation (**genetic erosion**). There are two important methods of germpalsm conservation or preservation.

(i) In-situ conservation, and
(ii) ex-situ conservation.

In-situ Conservation

Conservation of germplasm under natural conditions without altering its site is referred to as ***in-situ*** conservation. ***In situ*** conservation is achieved by protecting the area from human interference. An area where such conservation is done is called **natural park**, **biosphere reserve** or **gene sanctuary**. NBPGR (National Bureau of Plant Genetic Resources), New Delhi, established gene sanctuaries in Meghalaya for citrus, north-eastern regions for musa, citrus, oryza and *saccharum*.

Advantages

The wild species and the complete natural or semi-natural ecosystems are preserved together, in in-situ conservation.

Limitations

1. Each protected area will cover only very small portion of total diversity of a crop species, hence several areas will have to be conserved for a single species.
2. The management of such areas also poses several problems, of species management.
3. This is a costly method of germplasm conservation.

Ex-situ Conservation

Ex – situ conservation refers to preservation of germplasm in **gene banks**. This is considered to be practical method of germplasm conservation.

Advantages

1. It is possible to preserve entire genetic diversity of a crop species at one place.
2. Handling of germplasm is also easy.
3. Germplams conservation becomes cheaper.
4. ***Ex-situ*** conservation can be achieved in the following ways.
   (a) **Seed Banks:** Germplam is stored as seeds of various genotypes. Seed conservation is quite easy, relatively safe and needs minimum space. Seeds are classified, on the basis of their storability into two major groups.
      (i) **Plant Bank:** (**Field** or **plant bank**) is an orchard or a field in which accessions of fruit trees or vegetatively propagated crops are grown and maintained.
      (ii) **Shoot tip Banks:** Germplasm is conserved as slow growth cultures of shoot-tips and node segments. Conservation of genetic stocks:

(b) **Cell and Organ Banks:** A germplasm collection based on cryopreservation (at (–196°C) in liquid nitrogen) embryogenic cell cultures, somatic/ zygotic embryos they and called cell and organ bank.

(c) **DNA Banks**: In these banks, DNA segments from the genomes of germplasm accessions are maintained and conserved.

Germplasm evaluation

Evaluation refers to screening of germplasms with respect to its morphological, genetical, economic, biochemical, physiological, pathological, entomological and economic attributes. Evaluation of germplasm is essential for two reasons:

- To identify gene sources for resistance to biotic and abiotic stresses, earliness, dwarfness, productivity and quality characters.
- To get a clear pictures about the significance of individual germplasm line.

However germplasm evaluation has certain limitations, for example,

1. They require large areas,
2. They are expensive to establish and maintain,
3. They are prone to damage from disease and insect attacks,
4. They are prone to natural disasters, and
5. There are human errors in handling.

National Bureau of Plant Genetic Resources (NBPGR)

NBPGR established in 1976 is the nodal organisation in India for planning, conducting, promoting, coordinating and lending all activities concerning plant.

- Collection
- Introduction
- Exchange
- Evaluation
- Documentation
- Safe conservation
- Sustainable management of germplasm

The quantum of variability available and of diversity of various vegetable crops shows that India is one of the important centres/regions of variability of vegetable crops. The centre of origin/diversity of various vegetable crops reveals that a number of vegetable crops of economic importance and their wild relatives originated in this region. These genetic resources possess genes for wide adaptability, high yield potential including resistance/tolerance to biotic and abiotic stresses. The Indian sub-continent, thus,holds prominence as one of the twelve regions of variability in crop plants in global perspective.

Table 8.6: Gene Banks for various crops in India.

Institutes	Crops
Central Institute for Cotton Research, Nagpur	Cotton
Central Plantation crops Research Institute, Kasargod	Plantation crop
Central Potato Research Institute, Simla	Potato
Central tobacco research Institute, Rajahmundry	Tobacco
Central tuber crops research Institute, Thiruvananthapuram	Tuber crops other than potato
Central Rice Research Institute, Cuttack	Rice
Directorate of Oilseeds research, Hyderabad	Oilseeds
Directorate of Wheat Research, Karnal	Wheat
Indian Agricultural Research Institute, New Delhi	Maize
Indian Grassland and Fodder Research Institute, Jhansi	Forge and fodder crops
National research centre for sorghum, Hyderabad	Sorghum

International Crops Research Institute for Semi-Arid Tropics	Groundnut, Pearl millet, Sorghum, Pigeon pea and Bengal gram

Table 8.7: List of important International Institutes Conserving Germplasm.

Name	Institute	Activity
IRRI	International Rice Research Institute, Los Banos, Philippines	Tropical rice, Rice collection: 42,000
CIMMYT	Centre International de-Mejoramients de maize Trigo, El Baton, Mexico	Maize and wheat (Triticale, barely, sorghum) Maize collection – 8000
CIAT	Center International de-agricultural Tropical Palmira, Columbia	Cassava and beans, (also maize and rice) in collobaration with CIMMYT and IRRI
IITA	International Institute of Tropical Agriculture, Ibadan, Nigeria.	Grain legumes, roots, and tubers, farming systems.
CIP	Centre International de-papa-Lima. Peru	Potatoes
ICRISAT	International Crops Research Institute, for Semi-Arid Tropics, Hyderabad, India	Sorghum, Groundnut, Cumbu, Bengalgram, Redgram.
WARDA	West African Rice Development Association, Monrovia, Liberia	Regional Cooperative Rice Research in Collaboration with IITA and IRRI
IPGRI	International Plant Genetic Research Institute, Rome Italy	Genetic conservation.
AVRDC	The Asian Vegetable Research and Development Centre, Taiwan	Tomato, Onion, Peppers Chinese cabbage.

Review Questions

Q.1 Define the following:
(i) Biome

Q.2 How does climate affect the nature and locations of biomes?

Q.3 What factors influence climate?

Q.4 How does climate affect the nature and location of biomes?

Q.5 How have we affected the world's terrestrial ecosystems?

Q.6 Why do deserts and arctic tundra support a much smaller biomass of animals than do tropical forests?

Q.7 What type of biome are you in? Give three most important lifestyle activities which is harming your biome.

Q.8 List three characteristics of the type of vegetation found in hotter climate.

Q.9 List the characteristics of the forest of tropical monsoon regions.

Q.10 What are the unique adaptations that plants or the trees of the colder climate show.

Q.11 What is a biome? Into how many biomes the world biosphere is classified into? Mention three important characteristics of each one of them.

Q.12 What reasons are responsible for the ruthless exploitation of the temperate broad-leafforests?

Q.13 Differentiate taiga from boreal forest.

Q.14 Describe the responses shown by the animals and plants towards the environmental or climatic stress of
(i) Polar region
(ii) Desert
(iii) Tundra

Q.15 Discuss the ecological adaptations of plants and animals in relation to water.

Q.16 State true or false:
(i) Mature forest usually displays three distinct layers.
(ii) Savanna is tropical grassland.

(iii) Temperate boad –leaf forests are always evergreen.
(iv) Alpine tundra has permafrost.
(v) Breeding cycle is lengthened in Arctic regions.