Ecology

BIOGEOGRAPHY AND VEGETATION TYPES OF INDIA

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The study of the geographical distribution of species is called biogeography. It is both a biological and geographical science and its subject matter covers all forms of plants and animal life in the biosphere. The biogeographers investigate the species distribution patterns. The distribution can be of three types: geographical (horizontal distribution on the earth), bathymetric (altitudinal or vertical distribution) and geologic (distribution in the cline of time).

Biogeography originated from ‘Natural History’ during the latter half of eighteenth century when the Swedish botanist Carl von Linnae (Carolus Linnaeus) led the foundation of modern biological taxonomy and nomenclature. By the year 1804, von Humboldt had published 26 volumes on plants and related environmental data collected during the course of his extensive travel across South America. He is rightly credited as ‘Father of Plant Geography’. This work led to the emergence of two interrelated concepts: (i) the ’adaptation’ of organisms to their physical environment and (ii) the process of ‘natural selection’. These two concepts formed the basis of the Darwinian theory of evolution and origin of species.

Descriptions of the variations in vegetation cover on a regional or global scale focused attention on the very obvious significance of climate as an important ecological variable. There are broadly three types of climates: polar, temperate and tropical regions, which are primarily the temperature zones. These climatic zones have also been viewed as ’life-zones’ because each climatic zone is distinguished by a characteristic flora and fauna. Alphonse de Candolle, A. Griesebach and O. Drude laid stress on the variation in the form and structure of the major types of vegetation. Distribution and morphological features of vegetation show adaptation to the environmental conditions they are exposed to. Based on this approach, A.W. F. Schimper (1903) published his book entitled ‘Plant Geography on a Physiological Basis’. W. Koppen in 1918 drew a scheme of climatic classification which coincided with the boundaries between major types of vegetation. Concurrently, the importance of climate and vegetation as factors in soil formation were attracting attention in Russia.

Phytogeography (plant geography) is an accepted branch of Botany. It is the botanist’s study of the distribution of different types of plants or plant taxa (families, genera and species ). Phytogeographers aim to analyse the geographical range of particular taxa or flora to understand their origin, evolution and dispersion.

The nature of vegetation (the sum total of all plants in a given area) is dependent on the relative proportions of different plant species or communities.

Recent Trend

Until the beginning of the twentieth century, concepts of vegetation were essentially static. The importance of ‘time element’ gained increasing recognition following the pioneer work of Henry C. Cowles on changes in vegetation on a sand dune complex in Michigan. It demonstrated the process of succession in the establishment of a vegetation and emphasized the dynamic nature of both the physical habitat and its associated biological communities. F.E. Clements elaborated the concept of climax, determined by climate as the ultimate terminal stage in vegetation development. Many schools of biogeography have become strongly oriented towards palaeontological studies with the aim of reconstructing past environmental conditions and tracing the development of vegetation since early post-glacial times.
Factors influencing biogeographical distribution

Abiotic factors which affect the range of species distribution, include climate, soil-type, drainage, geological features and topography. Biotic factors influencing species range include characteristics such as the mobility of animals and seed or spore dispersal in plants and types of interactions of associated species. Biogeographical distribution is also influenced by the history of species under consideration and the geological histories of the area it occupies. Geographical isolation of populations of a species promotes evolutionary divergence through variation and mutation. These populations subsequently cannot interbreed and thus new species may result.

There are two problems of global distribution of flora which need explanation. 1. The existence of similar flora on opposite sides of wide ocean basins, and 2. existence of lush vegetable growth in the north and south regions during the past. Two theories have been proposed as a possible answer to the first problem.

Land-bridge theory- There is evidence that Europe and north America were connected by a land bridge linking Great Britain with Iceland, Greenland and eastern Canada. The hypothetical landmass, called Gondwanaland provided direct connections between South America, Africa, India and Australia over which the Glossopteris flora spread. Minor Land bridges existed between Madagascar and Africa and between Siberia and Alaska. It was across the latter that many plants and animals including man reached the North American continent during the Coenozoic.

Continental-drift theory- Alfred Wegener proposed that the disjunct landmasses containing similar geologic features were once continuous. They drifted apart as a result of the great rift in the crust of the earth. The surface of our planet is made of several large plates about 100-150 km thick which move very slowly across the surface of a more fluid core. Most of these plates have major land-masses or whole continent on them, so that as the plates move around, the continents also move with respect to one another. This movement is called continental-drift. It appears from various types of evidence that at one time all the present land masses were joined together in one huge super continent called Pangea. This began to split in half about 200 million years ago to form Laurasia and Gondwanaland. Gondwanaland was a Southern hemisphere continent, centered around the South Pole and composed of what are now India, Africa, Australia, New Zealand, South America and Antarctica. This super continent seems to have begun to break up in the Jurassic about 190 million years ago. Australia started to drift northward about 90 million years ago and gradually separated off from Gondwanaland until it was completely detached about 50 million years ago and moved northwards. The earliest contact of India with the Asian landmass took place towards the end of Palaeocene (Fig. 1).

Similarly, Laurasia was the northern hemisphere continent which broke up into North America and Europe and this separation formed the Atlantic ocean. By the early tertiary period, Gondwanaland and Laurasia had separated into the continents more or less as we know them today.

Wegener’s hypothesis explains some of the major problems of plant and animal distribution during the past. In order to explain certain facts he supplemented the theory of continental shifting with assumption that the poles are not permanently fixed, i.e., the theory of shifting poles or pendulum theory. It attempts to explain the repeated advance and recession of floras towards and away from the poles at several places in the geological series. The theory of ‘permanence of oceans and continents’ and of ‘polar origin of floras’ oppose the land-bridge and continental drift.
**Present pattern of biogeography**

Perhaps, due to its isolation, the best example of a distinct regional biota is found in Australia. This continent is famous for its present day fauna especially marsupials and monotremes. The monotremes are unique furry creatures which lay eggs, e.g., Duck-billed platypus. The young-ones lick the milk from their mother’s fur (no teats). They show incomplete regulation of body temperature which fluctuates around 30°C. Monotremes seem to combine reptilian and mammalian characters.

The flora of Australia has evolved independently of other regions. Angiosperms of several families (viz., Magnoliaceae, Nymphaeaceae, Palmaeae, Poaceae, Salicaceae, Winteraceae) were once widespread across Gondwanaland. In Australia, these families seem to have evolved further to produce a slow growing tough-leaved flora on nutrient-poor soils. As Australia moved towards the equator, its climate was affected by the cooling and icing up of Antarctica. After the mid-Oligocene (35 million years ago) Australia became drier and the climatic change followed the development of grasslands. The development of extensive grasslands in Australia led to the evolution of the grazing Marsupials such as kangaroos. Thus, the unusual species, now found in Australia are the result of species trapped there when it became isolated (the two grass families, Restionaceae and Poaceae probably evolved from common stalk
but the distribution of former is restricted to a few places including Australia in southern Hemisphere while
the latter have wide distribution with a large number of species). Its unique ecosystems and species (viz.
Banksia, Epacridaceae and Eucaluptus spp) have evolved and been preserved by isolation. The reverse of
this situation is found in South America. South America was also once part of Gondwanaland and must
have flora and fauna similar to Australia. About 6 million years ago South America became attached to
North America by Panama isthmus. Some southern species notably the marsupials (e.g., Opossum) reinvaded North America. About half of the genera of mammals, now found in South America, came from
the northern continent.

**Island biogeography**

Islands represent small isolated ecosystems with discrete boundaries. Islands can be formed in two
basic ways : by the disappearance of a connecting land-bridge from the main land if the sea rises and
floods an area in between or if the joining land is eroded or sinks. This makes the study of island population
easy as immigration and emigration are greatly reduced. Islands vary greatly in size, age, isolation, shore-
line structure, topography and geology. All these features affect the ecology of the communities which live
on and around them. Many isolated islands have high percentages of endemic species. Islands have
provided inspiration for evolutionary theories put forward by Darwin and Wallace.

There are several ways in which an organism can reach an isolated island. Some animals may
reach on island by flying and swimming and some by floating directly in the sea or attached to drift woods.
Air currents may carry light seeds and spores. Seeds can also be carried on bird’s feet or feathers or in their
digestive systems. Many species seem almost incapable of long-distance travel. As a result, many islands
lack certain groups. The Hawaiian islands, for example, have no amphibians, no terrestrial reptiles, no
gymnosperms and only one living mammal, a bat species. The present species of islands reflect not only the
species which first colonized them but also subsequent evolutions and extinctions. The endemic flora of the
Hawaiian islands contain about two thousand species but it is thought to have arisen from only about 275
immigrants and lacks many mainland tree species such as oaks, elms, figs, maples, mangroves and willows.

**The equilibrium theory of island biogeography** was proposed by MacArthur and Wilson in the
year 1967. At first, almost every organism arriving on the island will be a new species to the island. As the
number of species on the island increases, many of the new arrivals are likely to belong to the species
already present. The rate of immigration will decrease over time. If the island is close to the main land,
species will arrive quickly, so the immigration rate will be very high. If the island is away from the shore,
lke the Hawaiian Islands, then fewer species will reach it and the rate of immigration will be much lower
even at the beginning of colonization. Species, which have colonized the new island, run the risk of
extinction. If there are only a few species on the island, each will probably have a large population size
with little competition from the other species and the rate of extinction will be low. As the number of
species increases, the population size of some species will reduce and the probability of some species
becoming extinct, will, therefore, be higher. The rate of extinction rises as the number of species on the
island rises. If the island is large, there will be more room for viable populations of species than if the
island is very small. So the rate of species extinction of a species on a small island will be higher than that
in a large island.

* A new island, formed of volcanic ash, had emerged 30 km south of Iceland on Nov.15, 1963. It was
named as Surtsey which provided ecologists the opportunity to study colonization and primary succession
on newly emerged site.

If the number of species on the island is small, the immigration rate will exceed the extinction rate
and the number of species on the island will rise. As the number of species increases, the immigration rate
will fall, but the extinction rate will increase. Eventually, a point will be reached where the immigration
rate equals the extinction rate. At this point the number of species on the island reaches an equilibrium
point. Addition of new species balances the loss of species by extinction. Thus the equilibrium theory
predicts that any island will have a balanced number of species, which depend on its size and distance from
land. The number of species will be lower on isolated or small islands than on close or large ones. The
theory, however, does not include the addition of species *in situ* by evolution.
DISPERAL AND MIGRATION OF PLANTS

Dispersal- It merely involves dissemination from the parent and distribution to a new spot whereas migration implies also successful growth and establishment (Eccesis). Thus dispersal is a necessary forerunner of migration. Ever since the plants evolved on the earth, they have been occupying new areas. Their movement to new areas was possible through disseminules. The disseminules are most often reproductive structures such as spores seeds or fruits. In many instances they are special structure of vegetative nature (buds and bulbils), parts of plants, whole plants or group of plants. Several plants are most successful in colonizing vast areas by more than one means of dispersal. The common reed (Phragmites sp) is most widely distributed vascular plant of the world because it has the multiple advantage of a wind-dispersed, plumed fruit and a water-dispersed buoyant rhizome. In any case, a vast majority of disseminules go in vain. A single mushroom or puff-ball produces nearly 200 million spores. These spores are resistant to low temperature and desiccation and they are blown around the world. The dust seeds of orchids and minute one-seeded fruits of Balanophoraceae tend to be blown away in much the same manner as spores.

The disseminules that sink only slowly in still air and float in a light breeze may be transported far and wide. It happens with plumed seeds (having light tuft of silky hairs at one end) of Asclepias and Epilobium or with parachute-fruit of Taraxacum. In many trees, shrubs and lianas (e.g., pines, spruces, Bignonia), the seeds are winged. Cotton (Gossypium), Semal (Bombax) Willows (Salix) and Poplars (Populus) have seeds whose surface is covered with long silky hairs which may disperse about 100 m away. In the plants called ‘tumble-weeds’ (e.g. Salsola sp.), the detached portion bearing fruits and seeds tend to roll before the wind across open country. The backward slinging of the seeds out of fruits (the process is called jactitation) is evident in Papaver and Verbascum. Wind dispersal operates chiefly on free air-buoyant disseminules in open places (Fig.2).

In dense forest and sheltered areas, wind is little effective. Water bodies are insurmountable barrier to disseminules which cannot float for a long period. Thus it has been observed that plants depending on winged seeds for their dispersal, are rare on oceanic islands. The main mode of water dispersal is sea currents, river and streams and the rainwash and floods. Dispersal by animals and human agency is very diverse and generally species-specific.

A number of species show mechanical or clonal dispersal. Explosive spore discharging mechanism of some fungi may throw their spores as much as 15 feet. Several mistletoes and members of Euphorbiaceae can throw its seeds more than 40 feet. When the fruit of Ecballium elaterium is ripe, it ejects its seeds mixed with mucilage with a force that they fly for several feet through the air. The audible cracking of the pods of some Leguminosae forcibly ejects the hard and smooth seeds. When much of the growth is horizontal as a stolon or rhizome, a laterally spreading clone is formed that commonly roots at the nodes. Often the interconnections of such a clone decay so that it becomes represented by a number of dispersed parts. The individual clone of Pteridium aquilinum or Populus tremuloideas has thus, been estimated to have reached an age of 1400 years and have covered an area of more than 14 ha. The aggressive growth of overground runner and underground stems give plants a distinct advantage over their neighbours. Elms (Ulmus) can reproduce by suckers from underground roots at 45 m distance from the parent tree. Other such examples are the species of Clerodendron, Casaeria and Dalbergia.
Mechanisms of wind dispersal of disseminules: A, parachute-fruit of *Taraxacum*
B, plumed seed of *Asclepias*; C, winged pollen of pine; D, flattened seed of *Macrozamia*
with papyry wing; E, Fruit of maple (*Acer*) with wings; F, Fruits of *Tilia* attached with
bract for dispersal; G, Flattened fruits of ash (*Fraxinus*); H, capsule of poppy (*Papaver*),
seed dispersal by jactitation. (Adapted from N. Polunin, *Introduction to Plant Geography*,
1960, Longmans).

On reaching a new place, the propagules established themselves. The plants moving to new areas
had to acclimatize through morphological and physiological adaptations. Having established in the new
locality, plant reproduced, regenerated and formed somewhat stable populations. Hence, migration involves
transport and establishment of organisms from one place to another. The area where a plant or a taxon first
evolved and from where it dispersed to new areas is known as ‘center of dispersal’ or ‘center of origin’ of
the taxa (Table 1).

For indicating center of origin, there are many criteria. A fair one may be given by *Isoflors* which
are lines which delimit regions supporting equal number of species belonging to a single genus. From the
generic center outwards the number of species may be expected to decrease regularly which also suggests
the tracts of past migration. It may be followed backwards to converge upon the genetic center or center of
origin.
Table 1: The center of origin of some of the commonly used plants (based on palaeontological evidences).

<table>
<thead>
<tr>
<th>Plant</th>
<th>Botanical name</th>
<th>Center of origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td>Mangifera indica</td>
<td>India</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>Saccharum officinarum</td>
<td>India</td>
</tr>
<tr>
<td>Rice</td>
<td>Oryza sativa</td>
<td>India</td>
</tr>
<tr>
<td>Pea</td>
<td>Pisum sativum</td>
<td>India</td>
</tr>
<tr>
<td>Gram</td>
<td>Cicer arietinum</td>
<td>India</td>
</tr>
<tr>
<td>Coconut</td>
<td>Cocos nucifera</td>
<td>India</td>
</tr>
<tr>
<td>Maize</td>
<td>Zea mays</td>
<td>South America</td>
</tr>
<tr>
<td>Peanut or groundnut</td>
<td>Arachis hypogea</td>
<td>South America</td>
</tr>
<tr>
<td>Tobacco</td>
<td>Nicotiana tabacum</td>
<td>South America</td>
</tr>
<tr>
<td>Potato</td>
<td>Solanum tuberosum</td>
<td>South America</td>
</tr>
<tr>
<td>Tomato</td>
<td>Lycopersicum esculentum</td>
<td>South America</td>
</tr>
<tr>
<td>Barley</td>
<td>Hordeum vulgare</td>
<td>Asia Minor</td>
</tr>
<tr>
<td>Oat</td>
<td>Avena sativa</td>
<td>Asia Minor</td>
</tr>
<tr>
<td>Rye</td>
<td>Secale cereale</td>
<td>Asia Minor</td>
</tr>
<tr>
<td>Apple</td>
<td>Pyrus malus</td>
<td>Central Asia</td>
</tr>
<tr>
<td>Onion</td>
<td>Allium cepa</td>
<td>Central Asia</td>
</tr>
<tr>
<td>Tea</td>
<td>Camelia sinensis</td>
<td>South-East Asia</td>
</tr>
<tr>
<td>Banana</td>
<td>Musa balbisiana</td>
<td>South-East Asia</td>
</tr>
<tr>
<td>Most of the flowering plants</td>
<td>Triticum aestivum</td>
<td>South-East Asia</td>
</tr>
<tr>
<td>Wheat</td>
<td>Triticum aestivum</td>
<td>Mediterranean region</td>
</tr>
<tr>
<td>Brinjal</td>
<td>Solanum melounjana</td>
<td>Mediterranean region</td>
</tr>
<tr>
<td>Beet</td>
<td>Beta vulgaris</td>
<td>Mediterranean region</td>
</tr>
<tr>
<td>Carrot</td>
<td>Daucus carota</td>
<td>Mediterranean Region</td>
</tr>
<tr>
<td>Sorghums</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet Potato</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eucalypts</td>
<td></td>
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</tr>
</tbody>
</table>

**Barriers**

Migration is hampered by various barriers. Barriers act on different species in different ways. Some restrict intermixing of different contingents of a population or species. Other barriers may serve as a blockade beyond which the population cannot disperse. Some features may be barrier to expansion of the range of some species and not to others. Land is the great barrier for aquatic organisms and oceans are great barriers to terrestrial organisms. If a barrier serves to limit the range of many species, it becomes an important factor in the distribution of large number of organisms. The great barriers of land are mainly oceans, desert and large mountain ranges but minor barrier of many kinds occur all over the earth. Barriers may be generally categorized as follows-

- Climatic barriers- Temperature, wind direction, moisture, day-length.
- Physiographic barriers- Mountains, oceans, rivers and lakes.
- Edaphic barriers- Soil texture, soil nutrients and soil moisture.
- Biotic barriers- Specificity of plants to animals for dispersal of propagules or pollinating agencies or mycorrhizal associations.
- Reproductive barriers – Plants loosing the capacity for sexual reproduction in new environment.
**Routes of Migration**

Dispersal follows a set pattern and the routes of migration could be marked out based on proper understanding of the centres of origin and ecological requirements of a taxon. Croizat (1952) concluded that all angiosperms have migrated from south to north latitudes from three regions which are termed as ‘Gates of Angiospermy’: (a) African Gate (b) Western Polynesian Gate and (c) Magellanian Gate. All the three Gates were connected to an ancient land mass. Besides the three main Gates, there were two secondary migration centers from where the plants migrated. These were: a) Kalahari and Nigerian Centres in Africa and b) Roraiman, Ozark and Appalachain Centre in America. Dealing with a large number of species Croizat concluded that –

(a) The modern angiosperms evolved in southern latitudes,

(b) The plant migration actively took place in Jurassic and early Cretaceous period,

(c) The migration slowed down in the tertiary period, and

(d) The modern angiosperms evolved before the Jurassic period.

**GEOGRAPHY OF DISTRIBUTION**

About 65% of the world’s 2,50,000 flowering plant species are found in the tropics and about 20% of these are endemic species, contained in lowland and montane tropical forests and Mediterranean region. In aquatic systems, plants are generally smaller and less conspicuous in their environment than the animals. This relationship, however, is generally reversed in terrestrial ecosystems. The biota in the biosphere may be divided into several broad zones (cf. Scheme I) –

**Marine faunal regions:**

The broad zones of faunal regions (Fig.3) are as follows -

- **Littoral zone**- The shallower water region with light penetration to the bottom (littoral animals gradually decrease in number and kind downward into deep water).

- **Limnetic zone**- The open-water zone to the depth of effective light penetration, called the compensation level.

- **Profundal zone**- The bottom (benthic) and deep water area which is beyond the depth of effective light penetration (the large benthic zone of the sea is called Abyssal plain).

The broad groups of organisms harbouring different zones are as follows--

- **Pelagic**- Life in the open water, which can be- Plankton (floating organisms whose movement depends on current or sunlight; Nekton (swimming organisms) and Neuston (organisms resting or swimming on the surface).

- **Periphyton**- Organisms clinging to stems and leaves of rooted plants.

- **Benthos**- Organisms attached or resting on the bottom or living in the bottom sediments.

In the ocean, littoral animals gradually decrease in numbers and kinds downward into deep water. Littoral fauna can be categorized broadly into the following zones-

1. **Arctic**- covering mostly Eurasia & North America,

2. **Tropical**- It can be divided into two: Atlantic component covering tropical west African region and Pacific component having Indo-Pacific region which is often distorted by ocean currents and islands.

3. **Antarctic** which surrounds Antarctic land and cover south pole, and

4. **Intermediate or tropical fauna** between polar & tropical regions. The intermediates can be divided into Boreal fauna (from Atlantic coast of North America to northern coast of Europe) and Temperate fauna
which can be further divided into North-temperate and South-temperate zones. North temperate zone covers Japan to west coast of North America while south temperate zone is divisible into i. anti-boreal region (on tip of South America), ii. Kerguelen, iii. South Indian Ocean and iv. the South Australian and New Zealand regions. (cf. Scheme I).

Fig. 3a  Zonation of a typical sea marginal-profile.

Fig. 3b  Zonation of a typical lake marginal-profile.

Terrestrial biotic (life) realms:

The land of the Earth may be divided into 4 large biotic realms (Fig. 4)-

**Notogaea** - It covers Australian region where most distinctive biota are found. Special feature is the occurrence of the species of *Eucalyptus*, *Grevillea*, *Banksia* (plants) and egg-laying mammals (monotremes and marsupials) and running birds like emus, kiwi, cassowaries.

**Neogaea** - It covers Central and South America. The flora and fauna are less distinctive. There is no monotreme. Few marsupials (Opossum) and several amphibians, reptiles and poisonous snakes are present. Humming birds, macaws and sugarbirds are common. Among mammals, Chinchillas, Guinea pigs, marmosets and bats are common. Insectivores and ungulates are rare.

**Antarctogaea** - It covers Antarctic region only and have distinctive biota. Aquatic birds (penguins) often congregate on land.
**Arctogaea** - It covers Eurasia and Africa. It was earlier separated by *Tethys sea* of which Mediterranean region is the remnant. Much intermixing took place since it got joint and, therefore, its effect is largely lost.

Terrestrial faunal regions-

Zoological (faunal) regions coincide with all of the realms except Arctogaea which is very large and complex and can be divided into four regions: Nearctic, Palaearctic, Ethiopian, and Oriental. Thus, there are six terrestrial faunal regions as follows (Fig.5A) -

Nearctic- It includes north America except the tropical lowland of Mexico and Central America. The horses and camels seem to have originated in North America and spread to Asia before they disappeared in North America.

Palearctic- It includes Mediterranean area of North America and Eurasia except southeastern part. It is interesting to note that the biota of England and Japan are much nearer alike than the biota of China and India. (The Nearctic and Palearctic regions have been combined into Holarctic which also includes the intermittent land connections of North America with Eurasia).

Ethiopian- It includes Africa except the parts next to the Mediterranean sea. It has large population of endemic fauna. About 65% of mammals and 60% of birds are endemic.

Oriental- It includes South-eastern Asia and many of islands of East Indies and has distinctive biota that overlaps both east and west of Himalayan mountain barriers. Mammals, birds and reptiles are well represented.

Australian – It is identical with Australian biotic realm (Notogaea) and has been discussed earlier.

Antarctic- It is identical with the Antarctic biotic realm, Antarctogaea and has been discussed earlier.
Terrestrial floral regions –

The effectiveness of barriers in holding plants is quite different from the effect of the same barrier in holding animals. Hence, there is different movement across barriers and the faunal and floral groupings do not always match. Based on the proposal by Newbigin, world flora have been divided into several regions (Fig. 5B) as follows -

Pantropic region that includes nearly all the tropical regions of the earth and may be divided into New world and Old world. Coconut palm is the universal species across pan-tropic region.

Holarctic Region occupies most of the Northern Hemisphere beyond the tropics. The exceptions are in the southern Europe and northern Africa where the Mediterranean and desert region affect the boundaries. There is much in common between North America and Eurasia. The Coniferous forest (taiga) are especially noticeable and form extensive forest belt across northern Eurasia and North America.
MEDITERRANEAN REGION- ITS FLORA IS SUFFICIENTLY DISTINCT TO FORM SEPARATE REGION.

Desert Region-

It covers Sahara and Arabian desert. The vegetation of this region has developed great distinction in terms of adaptation to drought.

Australian Region- Its flora in itself is much more heterogeneous. It is possible to divide that belt into 3 subdivisions- Australian, South African and extra-tropical South American regions.

The world flora is divided into six plant kingdoms: Boreal, Palaeotropic, Neotropic, Australasian, Cape and Antarctic. The smallest of these is Cape Floral Kingdom but it has large number of species. There are nearly 8600 species of which 5800 are endemic and more than 1400 are Red Data Book species. Further, the flora is distributed over the world’s 12 major biomes. Each biome shows radical differences in species composition from one continent to another but exhibits closely similar physiognomy. Traveling north or south from the equator, we might pass through following biomes: 1. Tropical rain forests, 2. Tropical deciduous forests, 3. Tropical savannah, 4. Tropical thorn scrubs, 5. Desert, 6. Sclerophyllous Mediterranean scrub (maquis and chaparral ), 7. Steppe, 8. Mountain tops, 9. Temperate deciduous forests, 10. Temperate grasslands, 11. Boreal coniferous forests (taiga), and 12. Tundra. As regards to species richness, the heavily grazed Mediterranean scrub, dominated by annual grasses and legumes show maximum species richness. A 50m x 20m plot harbours more than 250 species (Crawley, 1997).

AREA DISTRIBUTION PATTERN

Some taxa are uniformly distributed in the area and give rise to ‘Continuous distribution’ while others may have isolated patches of areas widely separated apart. These constitute ‘Discontinuous distribution’ pattern.

a. Continuous Intercontinental ranges- the area of a taxon or of a vegetational feature is never really continuous. Of continuous intercontinental ranges, four main types may be considered: the cosmopolitan, the circumpolar, the circumboreal and the pantropic.

1. **Cosmopolitan**- These taxa are distributed all over the globe. They occur in all six widely inhabited continents, e.g., many weeds and lower groups of cryptogams.

2. **Circumpolar**- taxa distributed around the North or South Pole e.g. Saxifraga oppositaefolia, Eutrema edwardsii.

3. **Circumboreal**- taxa distributed around the boreal zone e.g. Ribes (Gooseberries) and Danthonia (poultry grass).

4. **Pantropic**- taxa occurring practically throughout the tropics and sub-tropics or at least widespread in the tropical region of Asia, Africa and America, e.g., Palm family (Areaceae).

b. Discontinuous ranges- In discontinuous or disjunct ranges, the plants are separated by wider gaps which cannot be overcome or crossed by the propagules. The main causes of discontinuity are environmental (due to particular topographic, climatic, edaphic or biotic characteristics of tracts separating the areas). Following are the familiar discontinuous ranges-

1. **Arctic – Alpine** : Taxa distributed in arctic region and in mountainous system of temperate zone. e.g. Salix herbacea, Saxifraga oppositaefolia.
2. **North Atlantic**: Taxa distributed in North America and Europe and also some times locally in Asia, e.g. *Lycopodium inundatum* and *Spiranthes* sp.

3. **North Pacific**: Taxa distributed chiefly in North America and Eastern Asia, e.g. *Torreya* (Torrey pine) *Symlocarpus foetida*.

4. **North—South American**: Taxa distributed in North and South America but lacking continuity in between, e.g. *Sarraceniaceae* (pitcher-plant family)

5. **Europe – Asian**: Taxa distributed in Europe and Asia but lacking continuity between. e.g. *Leontice altaica*, *Cimicifuga foetida*.

6. **Mediterranean**: Taxa distributed at European and African shore of Mediterranean sea. e.g. *Platanus*

7. **Tropical**: Taxa distributed in two or more separate tropical regions. e.g. *Buddleia*

8. **South pacific**: Taxa distributed at least in South America and New Zealand. e.g. *Jovellana*

9. **South Atlantic**: Taxa distributed at least in South America and Africa. e.g. *Asclepias*.

10. **Antarctic**: Taxa distributed on Arctic mainland and parts of South America, New Zealand and Austral islands. e.g. *Nothofagus*.

11. **Gondwana type**: Taxa distributed in more than one continent which tends to embrace Africa, Madagascar, India and Australia. e.g. some sedges.

Polytopy is the occurrence of a species in two or more separate areas. Such species are termed polytopic or polyendemic.

**RESTRICTED DISTRIBUTION**

**Relic areas and Relics**

Relic species (relics) are the remnants of past flora, e.g., *Trapa natans* (water chestnut) in Scandinavia, *Sequoia* (giant redwoods in Northern Hemisphere and *Pinus sylvestris* (scots pine) in the mountains of Europe. On the basis of the type of natural habitat change, relics may be further distinguished into several types.

**Vicarious areas and Vicariads**

The vicarious areas are the areas belonging to closely related taxa (vicariads) derived from the same common ancestor and tending to be mutually exclusive of one another in naturally (without human interferences) occupying separate areas. This is the case with many subspecies and closely related species. From their very nature ecotypes often tend to be vicarious as do the extreme ‘ends of clines’, e.g., races of *Pteridium aquilinum* (Bracken fern) inhabiting different parts of the world; Wood and alpine *Myosotis*, *M. sylvatica* and *M. alpestris*, and common and alpine *Timothy*, *Phleum pratens* and *Phleum alpinum*. Vicariads tend to evolve chiefly about the periphery of a migrating ‘parent taxon’. Here new characters may arise by mutation or other chromosomal changes and help the better adapted generation to survive under conditions which are less favourable to the parent. Vicariads may also arise as a result of hybridization.
Endemics

Endemic plants are those whose range is confined to a single restricted area, not extending beyond some one region, island or other circumscribed tract.

There are two main types of endemics: Relic endemics or epibiotics and Micro-endemics.

1. Relic endemics or Epibiotics- The old ones whose range was once far more extensive than it is today and they are survivors or remnants of former floras. A good example of this type of endemism is furnished by the giant redwoods of the Western United States which used to be extremely wide spread in the Northern Hemisphere.

2. Micro-endemics- They are characteristic of newer portion of the earth’s surface. Thus, when ecological conditions change within a natural region, there is a tendency for new forms to evolve. The new forms may be confined to the region owing to its special habitat conditions or because of some physical barrier. Such plants are also called as neo-endemics.

Relic endemics tend to be deficient in biotypes and are usually recognized by their relic characters and geographical isolation, their small amplitude of variation and narrow restrictions to particular ecological conditions, their relatively small chromosome number and their generally retrogressive nature. Ginkgo biloba is a good example of relic endemics. On the other hand, neo-endemics, being secondarily derived types, are progressive in characters e.g. Primula, Impatiens and Rhododendron. Neo-endemics generally show Polyploidy. Polyploids are found in most of the major groups of plants. Among angiosperms, perennial herbs are often polyploids in contrast to their annual relatives. These herbs are often more vigorous than their diploid relatives even of the same species. Polyploids may show very different ecological preferences and geographical distribution from their diploids. They are more hardy, more northerly and high alpine in their distribution. They have greater tendency to adapt asexual means of reproduction than related diploids. Polyploids, arisen through hybridization (allopolyploids), have a wider geographic range than diploids. Thus, the phenomenon of polyploidy has considerable significance in ecological and geographical connections.

Plants, which appear to be mutant and have been encountered only in one place but are unlikely to persist, are called as pseudo-endemics. Plants, which have arisen in relation to particular habitat conditions, may be called as ecological endemics. Some endemics, which are confined to very limited areas, such as a single small island or mountain peak, may be called as local endemics. Such restriction is usually due to their recent origin or high specificity with regard to habitat conditions or to impossibility of further expansion. Isolated islands are particularly rich in endemics.

FEATURES OF INDIAN FLORA

General features-The flora of the region represents the sum total of different types and kinds of plants. Flora refers to the list of plant species found in a given geographical area. In a floristic study, the number and quantity of plants in an area need not be estimated while these estimates are necessary for characterising vegetation. There are nearly 2,50,000 species of higher plants all over the world which include bryophytes, pteridophytes, gymnosperms and angiosperms (Wilson, 1992). The flora of India shares well over 45,000 species (BSI, 1981). In India, there are over 17,000 species of angiosperms amongst which forty-two families have more than 100 species, eighty-one families have fewer than 20 species while thirty-three species have single species. Among families having more than 20 species, 65 have more than 50% endemics. The generic endemism for India is 7.3%, i.e., 134 out of 1831 genera of dicotyledons are endemic. Out of 5725 endemic species 3470 species are endemic to Himalayas, 2051 to peninsular India and 239 in Andaman and Nicobar Islands. The largest family of flowering plants in India is the Orchidaceae, with nearly 1700 species. The 10 most dominant families in Indian flora are Orchidaceae, Leguminosae, Poaceae, Rubiaceae, Euphorbiaceae, Acanthaceae, Asteraceae, Cyperaceae, Lamiaceae and Urticaceae. Except for the Lamiaceae and Asteraceae which are more temperate than tropical, the rest of the families have largely tropical species.
The low position in India of the Asteraceae, which is the richest family of flowering plants in the world and which usually tops the list in the flora of many continents, is surprising. If the Himalayan and alpine species of Asteraceae are excluded, this family will not feature even in the first ten dominant families in the Indian vegetation.

Endemic flora of India

Although India is connected by land with a number of continents with distinct floral elements, it has a large proportion of endemic flora. At least 47% of the dicot plant species of India are endemic. The maximum endemic dicots occur in the Himalayas. The reason for such a high percentage of endemic plants in India is the presence of lofty mountains of the Himalayas on the north, north-east and north-west of the mainland and the sea in other directions. Following are some of the common plant genera, endemic to India-

- **Lepidostemon** (Brassicaceae),
- **Gynocardia** (Flacourtiaceae),
- **Chloroxylon** (Rutaceae),
- **Beddomea** (Meliaceae),
- **Butea** (Fabaceae),
- **Caesulia** (Asteraceae),
- **Hemiphragma** (Scrophulariaceae),
- **Phlogocanthus** (Acanthaceae),
- **Odontomella** (Acanthaceae),
- **Eriophyton** (Lamiaceae),
- **Phacellaria** (Santalaceae).

Neo-endemic elements in the Indian flora

A number of distinct group of plants have migrated to India from the neighbouring regions. The Tibetan and Siberian plants occur in the alpine belts whereas a number of Chinese and Japanese species occur in the temperate regions of India. As many as 570 European species are represented in Indian flora and equal number are believed to have mid-eastern affinities. The Malaysian element, however, is most dominant in India, Its migration having been facilitated by a land connection between the two countries. Due to high Himalayan barrier the Tibetan and Sino-Japanese elements are not well represented. Australian and American elements are still less represented due to sea barriers.

VEGETATION OF INDIA

India is a mega-diversity zone where almost all biogeographic regions are represented. Though the area of the country is only 2% of the world landmass, it has over 5% of all known species of plants and animals. The north-eastern Himalayas, Eastern Ghats, Andaman and Nicobar Islands and the wetlands, and river valleys are location of special significance. These areas have high species diversity and high level of endemism. There were 18 globally recognized biodiversity hot-spots in lowland tropical forests, montane tropical forest and Mediterranean region, including the Western Ghats of India (Davis et. al. 1994) containing over 1600 endemic plant species. The number of biodiversity hot-spots increased to 25 and currently, it has gone up to 34. Now, the north-eastern Himalayas have also been included into biodiversity hot-spots. The Botanical Survey of India has brought several volumes of *Red Data Book* (a term for the list of critically rare, endangered or vulnerable species, coined by the Species Survival Commission of IUCN). However, information on species abundances and their functional attributes is still rare.

There are remarkable structural similarities between the rain forest of the three great tropical regions- Indo-Malayan, African and the Central and South American regions. Floristically, they differ greatly which indicates that the components of these remarkably similar looking forests have evolved in parallel and in isolation. The rain forests of the Indo-malayan regions are dominated by Dipterocarps and may make up 80% of emergent trees and 40% of understorey.

There are emergent legumes like *Koompassia* and *Erythrina*. Species like *Eurya japonica*, *Macranga* and *Trema* grow as pioneer weed trees. The swamp forest genus *Barringtonia* is quite common. Certain Meliaceae like *Toona* and *Dysoxylum* are commonly met in Indian moist-tropical forests (Table 2). *Ceiba pentandra* is cosmopolitan tropical species and grows everywhere if the soil moisture is adequate.
Table 2. Examples of families and genera containing dominant and abundant woody plants in the major Indian moist tropical forests.

<table>
<thead>
<tr>
<th>Family</th>
<th>Genera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dipterocarpaceae</td>
<td><em>Dipterocarpus, Hopea, Shorea</em></td>
</tr>
<tr>
<td>Leguminosae</td>
<td><em>Acacia</em></td>
</tr>
<tr>
<td>Meliaceae</td>
<td><em>Toona, Dysoxylum</em></td>
</tr>
<tr>
<td>Moraceae</td>
<td><em>Artocarpus, Ficus</em></td>
</tr>
<tr>
<td>Anacardiaceae</td>
<td><em>Mangifera</em></td>
</tr>
<tr>
<td>Dilleniaceae</td>
<td><em>Dillenia</em></td>
</tr>
<tr>
<td>Rubiaceae</td>
<td><em>Anthocephalus, Adina</em></td>
</tr>
<tr>
<td>Myrtaceae</td>
<td><em>Syzygium</em></td>
</tr>
<tr>
<td>Epiphytes</td>
<td>Ferns, Orchidaceae, Asclepiadaceae</td>
</tr>
<tr>
<td>Secondary plants</td>
<td><em>Macranga, Eurya, Melastoma</em></td>
</tr>
</tbody>
</table>

*Melia and Psidium are introduced genera which commonly occur.*

Characteristics of the vegetational types of India

In any case, the main vegetational type or climax community is regional and climatic. At places, the vegetation is arrested at some seral or sub-climax stages. The main types of vegetation are characterized by the life-form of dominants and co-dominants. In India different vegetational types are as follows:

1. Tropical forests
2. Sub-tropical and warm temperate rain forests
3. Coniferous forest
4. Savannah and Grasslands
5. Semi-desert scrubs and desert vegetation
6. Sea-shore vegetation
7. Seral and edaphic communities
8. Altitudinal effects

1. The tropical forests

Several kinds of tropical forests such as tropical rain forest, seasonal tropical forests, dry tropical forests, sub-tropical rain forests and tropical swamp forests all abound in tall trees of diverse species. Tropical rain forests mostly occupy flat and rolling topography extending up the lower slopes of mountains. In India the chief development of tropical rain forest is in Malabar Coast (Western India). The temperature here is relatively high and uniform and the annual rainfall exceeds 2000 mm. A number of insects, frogs, lizards, snakes, birds, squirrels, monkeys etc. flourish in the canopy and many of which never touch the ground during their lives. There is no regular seasonal change and flowering and fruiting occurs almost all the time in some or other species. The dormant buds are most often small and unprotected but may develop after several or many years giving rise to cauliflory (the formation of flower on old bare wood). Most of these forests have conspicuous emergents e.g. *Dipterocarpus, Erythrina, Koompassia*, and *Ilex*. The taller forests are found in areas with an alteration of humid and drier seasons, high total precipitation and well drained soils. Usually there are 3 strata of trees. The lowest tree strata is usually dense and dominated mostly by
dicotyledons but the large palms and bamboos are common and quite often the tree fern (Cyathia sp.) is present. They show mixed dominance and no single species has so many individuals. The leaves are usually leathery with smooth and shining dorsal surface. They are mostly oblong lanceolate to elliptical in outline often with extended drip-tips. Trees often show plank buttresses. *Ficus* is one of the richest genera of such forests. Several of the *Ficus* species begin their life as epiphyte but later send down roots to the soil and become independent and often kill the tree which originally supported them. Since their aerial roots gradually engulf the host trunk, these figs are called *strangler figs*. They overtop the host and deprive it of light eventually killing the host trees. There are a few other genera (viz. *Spondias*) which can strangle host trees.

The group of plants which are dependent on external mechanical support are called climbers and vines. The woody ones, called lianas (or lianes), are very large. They may he thin wire like or rope like and may hid in the mass of foliage or hang down in the form of large loops. They pass from tree to tree and link the tree crown firmly. They may be as simple and thin as *Echnocarpus* sp. to as complex and massive as *Acacia concina* and *Caesalpinia bonduc*cella, they may be as smooth as *Tiliacora acuminata* and as thorny as *Mesoneurum cucullatum*. Some lianas are tendril-climbers with modified leaves, leaflets or stipules; others are twiners; some have adhesive root system while others are hooked. They are not directly attached but are hoisted into or hanged from canopy. Climbing palms or rattans (*Calamus* spp.) are often prominent.

Plants which grow attached to the trunks, branches, and even living leaves of the trees, shrubs and lianas are called epiphytes. They do not necessarily have any ill effects upon the supporting host. Their number and diversity are great involving cryptogams of all lower groups as well as pteridophytes and flowering plants. According to recent estimate about 10% of all the vascular plants are epiphytes which are represented in 19% of families, the largest being Orchidaceae. Other important families of epiphytes are Bromeliaceae and Cactaceae.

The Understorey of the forest is dominated by shrubs and small trees. Where the tree strata is not dense and the forest floor is exposed, a green ground vegetation develops composing mostly of herbs including ferns. Among herbs, Rubiaceae and Melastomaceae are dominant with some grasses and sedges. In addition to fungi and bacteria there are small flowering plants (certain orchids, some Gentianaceae, Triuridaceae and Balanophoraceae) which obtain their nourishment from dead organic matter. They are chiefly found in deep shade. There are root parasites growing on the ground and semi-parasites growing epiphytically on the trees. *Rafflesia* presents a true parasitic genus on the roots of Cissus vine. On the other hand, epiphytic semi-parasites all belong to the Mistletoe family (Loranthaceae e.g., *Loranthus, Viscum*). They are woody shrubs occurring on the branches of taller trees.

The vegetation of old-fields and forest edges also show a major share of woody species (robust herbs, shrubs, lianas and small trees) intermixed with grasses. About 13% of the total forest area of India is covered by natural and planted bamboo. It is mentioned as tree-grass and is one of the most useful plants of the world. Important bamboo genera are- *Bambusa, Arundinacea*, and *Dendrocalamus*.

Seasonal tropical or monsoon forests occupy the regions having pronounced dry season of several months. They occupy a much greater area of Indian tropical forests. They tend to be more open. Most trees shed their leaves during one season and the degree of defoliation depends upon the severity of the season. The dry season is often the period of flowering. The trees have thick bark, exhibit growth-rings in the wood. Plank buttresses are rare (e.g., *Salmalia*). The trunk is massive and short and the leaves are thin and large (e.g., *Tectona grandis*). The climbers are fewer and smaller than in rain forest. The undergrowth is often luxuriant consisting of shrubby thickets. Bulbous and other geophytes (e.g. *Typhonium, Plesminium* and *Crinum*) are quite common. The density and greenness of vegetation sharply declines in dry tropical forests. Still lesser rainfall and longer dry season promote tropical thorn forests.

2. **The sub-tropical and warm-temperate rain forests**

The sub-tropical rain forests may be witnessed on lower hills of Eastern Himalayas. They overlap much with tropical rain forests in species composition but the seasonality is manifested in semi-evergreenness due to the presence of a number of deciduous elements. Warm-temperate rain forests occur on the upper hills in north-eastern India. Both of these rain forests have several trees in common. They are characterized by species of *Aesculus*, Bamboos, *Castanopsis, Quercus, Magnolia, Pinus, Schima*, tree fern and large shrubs. A number of truly temperate elements (e.g. Rhododendrons and a few conifers) are found on the upper hill-tops.
3. Coniferous (Temperate) forests

These forests occur in the temperate zone of the western and eastern Himalayas. The formations of warm temperate coniferous forests contain the species of Quercus, Fagus, Betula, Careya, Juglans, Acer, Tilia, Ulmus, Liriodendron and Populus, and the temperate forests contain Cedrus deodara, Picea morinda, Abies pindrow, Taxus baccata and Vaccinium sp. Species of Alnus, Prunus, Sorbus, Hedera and Rubus also occur. In the eastern Himalayas, the common conifers belong to the species of Abies, Picea, Larix and Tsuga in addition to Pimus khasiana (khasi pine).

4. Savannah and Grassland

The vegetation, derived mostly from the degradation of forests due to recurrent biotic disturbance, is savannah woodland which covers a greater part of the terrestrial vegetation of India. Savannah presents mostly a park or orchard-like appearance- a landscape typically of plains of tall grasses with scattered trees and shrubs. In hollows (lowlands), trees frequently grow close together to form woods whereas on ridges (upland), trees are sparse or wholly absent resulting into uniform grassland vegetation.

There is no true climax of natural savannah in India. The trees are commonly stunted and most of them belong to Leguminosae. Based on the edaphic and climatic conditions, savannah may be recognized into several types. In sal savannah where Shorea robusta is the dominating tree, grasses like Cymbopogon, Imperata, Eragrostis, Themeda, Erianthus and Cyndon commonly occur. In high savannah of Assam valley dwarf trees like species of Emblica and Syzygium are scattered with grasses like Imperata, Vetiveria, Eragrostis, Cyndon, Deschampsia, Arundinella, Saccharum etc. Dry savannah of Punjab, Haryana, Orissa, Bihar, Jakhank hand, parts of Tamil Nadu shows scattered tress of Emblica officinalis, Crotalaria hirta, Madhuca indica and Pterocarpus marsupium with grasses like Arundinella, Apluda, Themeda, Chrysoptogon and Deschampsia. Alluvial flats of Gangetic plains have trees like Terminalia arjuna, Tamarindus indica, Dalbergia sissoo, Zizyphus sp., Butea monosperma, associated with grasses like Arundinella, Saccharum, Erianthus and Eragrostis. Alkaline and saline, scrubby savannah shows small trees and shrubs like species of Phoenix, Borassus, Acacia, Calotropis, Zizyphus with grasses like the species of Eragrostis and Imperata on alkaline soil in the form of scrubs. It is common in different stretches throughout northern India. Vindhyana hilly tract and Central India have Bamboo savannah along with other grasses and few scattered trees.

Sites receiving still lesser rainfall may also have savannah vegetation but the trees are sporadic with relatively stunted growth. The vegetation is referred to as grassland. The grasslands are found in extensive patches all over the country and thus they form an important component of terrestrial vegetation. Grasslands are composed of herbaceous spermatophytes of two types (1) Grasses (Poaceae) and sedges (Cyperaceae), referred to collectively as graminoids and (2) forbs, i.e., other herbs including legumes. Dwarf shrubs that do not exceed the height of grasses are also found while taller shrubs occur as isolated individuals. Most of Indian grasslands tend to be stable under the influence of biotic disturbances such as fire, grazing and scraping practices. Apart from high Himalayan meadows, there is no climatic climax of a grassland in India.

Indian grasslands are mostly found under monsoon belt where most of the rainfall occurs during July-August. They are plagio-climaxes. The amount and period of rainfall influences the structure and composition of plant communities in the various eco-climatic zones. The grassland communities of India are rich in species and have the character of savannahs with widely scattered trees. Low bushes with small and hard evergreen leaves and prickles or thorns may occur among the grasses. The trees which may appear with stunted growth, generally belong to palms, Acacias and other legumes. In lowlands, tall grasses may form impenetrable thickets.

The grasses which commonly occur in Indian grasslands (excluding alpine region) include following genera- Dicanthium, Eragrostis Cyndon, Dactylctenium, Sehima, Chrysoptogon. Heteropogon, Ischaemum, Themeda, Saccharum, Arundinella, Phragmites, Deschampsia, Cymbopogon, Aristida, Cenchrus, Ceriops, Bromus, Bracharia, Sporobolus, Apluda, Andropogon, Imperata, Digitaria, Thysanolaena etc. The most common forb genera include Desmodium, Alysicarpus, Indigofera, Aschenomene, Cassia, Crotalaria, Zornia, Tridax, Vernonia, Gomphrena, Launaea, Evolvulus, Rungia, Boerhaavia, Scoparia, Cancsora, Lindernia etc. Because of their origin from degeneration of forests, these grasslands do contain several shrubs and trees. Prosopis, Zizyphus and Capparis are common to semi-arid
5. Desert vegetation

The hot desert can support only the scanty growth of scattered plants. The area generally receives intense solar radiation and is exposed to high sweeping winds which cause yellowish sand-dunes and rugged rocky floor. Occasionally, luxuriant oases may be found. The north-western India has extensive hot desert which receives little rain (20 cm or less per annum) or even perennial absence of rains. Shrubs and shrubby trees have long roots reaching up to 10 m or more deep. The plants are densely compacted and often closely covered with hairs and spines. Arid bushlands occupy a part of Thar desert. Scrubby and thorny Acacias, cactus-like Euphorbias and large-leafed Agaves, Aloeas and Yuccas are characteristic inhabitants. Many plants like cacti and cactus-like Euphorbias store water in their massive stem or other swollen organs. These succulents have an extensive system of roots, spread near the surface of the soil to readily absorb water when it becomes available. At such times annuals (ephemerals) spring up and quickly complete their life cycle and geophytes send up their aerial shoots for flowers and fruits. The shrubs or thorny scrubs, commonly have very small xerophilous leaves, others have leaves reduced to scales. Photosynthesis is carried out by green twigs or succulent stems. The sandy or gravely beds of dried up water courses (vadis) grow Tamarix and grass-tussocks.

6. Sea-shore vegetation

Sea-shore harbours a characteristic swamp forest which develops on mud flats and gets dominated by Mangroves. Mangrove vegetation is common at quiet bays ending river estuaries where tidal water causes the deposit of river sediments. On the resulting flats and deltas (e.g. Sundarban) the water-borne seeds and seedlings soon colonize. The prop-roots of mangrove trees also cause deposition of silt forming new mud-flats which extends the forest year after year. Numerous slender conical aerating roots grow vertically out of the mud. These roots have breathing pores and contain numerous air spaces that conduct oxygen to the underground part. These aerating roots are pneumatophores bear fine rootlets for absorption. Many mangroves (e.g. Rhizophora mangle) have viviparous development of their seeds. Sometimes, mangroves are replaced by palms (such as Nipa fruticans and Cocos nucifera). Where the trees are less close together, there is a dense undergrowth of shrubs and small trees. The leaves are usually leathery, succulent and sword like (e.g., Pandanus and Cocos). A characteristic tree in such situation is Barringtonia acutangula. In other instances, littoral forest may be deciduous, largely dominated by a single species (such as Casuarina equisetifolia).

7. Seral or Edaphic communities-

In eutrophic waters, the early stages consist of free-floating plants and communities of submerged aquatics followed by rooted, floating-leaf vegetation consisting of water lilies etc. This prepares for the reed-swamp stage which in turn is succeeded by scrub or low forest. The hydroseres may start in deep waters that gradually become shallower with the deposition of various materials. The floors of the body of shallow water is occupied by the species of Chara, Nitella and Najas and of some aquatic mosses. The submerged aquatics also include Potamogeton, Vallisneria, Ceratophyllum and Elodea and most of them are rooted having floating leaves. The surface of water may be fully covered by floating plants (pleuston) such as duckweeds (Lemma) and water-haycinth (Eichhornia crasipes), Pistia, Utricularia, Hydrocharis spp. The rooted plants with floating leaves (e.g., Nelumbo nucifera) project out of water. As the water gets much shallower, the reed-swamp stage follows which is characterized by the species of Phragmites, Scirpus, Typha, Carex and Cyperus. These are marshy plants (helophytes) with roots under water and shoots extending high up into the air. Swampy grounds may frequently be occupied by certain palms, Eugenia and Barringtonia spp. Ferns, mosses, liverworts and weeds can be plentiful.
Scrubs and forests that form parts of secondary or deflected successions, have been caused particularly by man and his domesticated animals. When they are subjected to recurrent fires (for shifting cultivation) or persistent grazing, deflected succession sets in and lead to biotic plagio-climaxes. The vegetation on such sites is characterized by the abundance of the species of *Pteridium, Eupatorium, Lantana, Bambusa* and *Imperata*.

9. **Altitudinal effects**

More and more temperate species enter as we ascend to the upper forested zones on tropical mountains. The total flora tends to decrease. Leaves in general become fewer and slender. The epiphytes are usually smaller and herbaceous, mostly limited to ferns and bryophytes or lower cryptogams. Liverworts become numerous and with lichens blanket the trunk of the trees. At still higher altitudes dwarf trees and shrubs are common. The characteristic trees are silver fir, silver birch, junipers and shrubby rhododendrons. The trees of the sub-alpine zone are reduced in size and their foliage is more xeromorphic. As the trunk becomes shorter and thicker, the branches enlarge and the growth becomes irregular resulting into ‘elfin wood’. The extremely twisted and stunted trees are known as ‘krumholz’. The elfin wood and finally krumholz marks the termination of the forest and the beginning of the treeless alpine zone which is vegetated by scrubs, tundra species and heathy or herbaceous vegetation. At mountain tops, above timberline, the characteristic plants are dwarf herbs growing close to the soil. They bear beautifully coloured flowers in early summer and autumn.

**ECO-BOTANICAL REGIONS OF INDIA**

India has been divided into a number of eco-botanical regions. Puri et. al, (1990) described Indian vegetation into the following eco-botanical regions-

1. **Western Himalayas**

The Himalayan mountains from Kumaon to Kashmir are characterized by a rainfall of 1000-2000 mm per annum with considerable variation between outer and inner valleys. The inner valleys receive very low monsoon rainfall but high snowfall. The climate generally becomes drier to extreme towards west. The vegetation is divided into altitudinal zones such as sub-montane zone up to about 1500m, Temperate zone from 1500 to 3630m, and an Alpine zone above snow-line (Fig. 6).
Fig. 6. VEGETATION ZONES IN THE WESTERN HIMALAYAS
The sub-montane zone comprising the Siwaliks has Shorea robusta forest, interrupted by tracts of savannah vegetation, riparian forest and swamps. In savannah, trees of Bombax ceiba, Butea monosperma, Lagerstroemia parviflora, Acacia catechu with Zizyphus sp. are present. Dalbergia sissoo and Acacia catechu are the main trees in the riverian tracts. The swampy areas have a vegetation of Toona ciliata, Bischofia javanica, Albizia procera, Ficus glomerata, Syzygium cumini, Barringtonia acutangula, Trewia nudiflora and Calamus tenuis with a thick undergrowth of evergreen bushes, ferns etc.

In the bhabar tracts with low water table and drier soil conditions, mixed deciduous forests with species of Terminalia, Anogeissus, Stereospermum, Emblica, Adina and Eugenia spp. with or without sal are present. Dendrocalamus strictus is commonly found. Pinus roxburghii comes on special habitats such as quartzite and boulder conglomerates on the top of hills. In burnt and heavily disturbed areas, thorny species of Zizyphus, Carissa, Acacia and constituents of open degraded forests such as Mallotus philippensis, Holarrhena antidysenterica, Ehretia laevis, Cassia tomentosa, Ficus benghalensis, Adina cardifolia and even Terminalia tomentosa and Shorea robusta are found.

In the temperate zone forests, five oak species, Quercus semicarpifolia, Q. dilatata, Q. incana, Q. ilex and Q. glauca are present forming climax community. The oaks are associated with a number of deciduous broad-leaved trees such as Acer, Aesculus, Populus, Ulmus, Alnus, Betula, Cornus, Prunus, Rhododendron arboreatum and R. complanatum. Fraxinus, Xanthoxyloides and Buxus are present in the inner valleys. In the outer monsoon zone, Picea and Abies occur in areas with heavy snow-fall.

The Alpine vegetation consists of high level silver-fir, birch, Juniper, Rhododendron. Deodar is scanty. Even at 3000m elevation quartzite carries Pinus roxburghii and riverian alluvium at 1500m elevation exclusively bears deodar showing that altitude has little effect on the distribution of these conifers.

2. Eastern Himalayas

The eastern Himalayas constitute the humid region from Sikkim eastwards. This is also divided into tropical, temperate and alpine zones according to altitude. The eastern Himalayas is distinguished by higher monsoon rainfall, scanty snowfall and higher temperature and humidity compared to the western Himalayas.

The tropical zone in the Eastern Himalayas is also formed of sal forests with patches of riverine forests, mixed deciduous forests, savannahs and swamps. This corresponds to Siwalik zone. The mixed deciduous forests consist of Sterculia villosa, Lagerstroemia parviflora, Terminalia spp. Anocephalus cadamba, Toona ciliata, Bauhinia spp., Stereospermum sp. These forests are also developed on the Siwalik’s formations and on the account of high rainfall and deep clayey red soils most of the constituents of eastern sal forests are evergreen. The undergrowth in these is also more luxuriant than in the western sal forests. The evergreen forests in this zone are composed of Aesculus punduana, Artocarpus chaplasha, Michelia champaca, Cinnamomum, Schima wallichii and Dillenia indica. The common bamboo is Dendrocalamus hamiltonii. The savannah in this part of the Himalayas are usually moist with tall grasses and trees of Albizzia procera, Bischofia javanica and Bombax ceiba.

The temperate zone is divisible into the lower and upper zones. The vegetation in the lower temperate zone is dominated by broad-leaved species of oaks such as Quercus lamellosa, Q. lineata, Michelia excelsa, Pyrus, Symlocos, Eurya, Meliosma, Castanopsis etc. The upper zone has conifers like Abies, Picea, Larix and Tsuga with Junipers and Rhododendrons. The common bamboo is Arundinaria racemosa.
In the Alpine zone, the commonest species are Rhododendrons and Junipers. (Fig.7).

**Fig.7. VEGETATION ZONES IN THE EASTERN HIMALAYAS**
The vegetation of the Eastern Himalayas broadly differs from that of Western Himalayas by having less conifers and much more broad-leaved forests. There are more than 20 oak species here as against five in the Western Himalayas and the Rhododendrons have greater abundance and varieties. There are tree ferns and orchids which greatly outnumber those in western Himalayas.

3. Gangetic Plain

Gangetic plain comprises Uttar Pradesh, parts of Delhi State and the plains of the neighbouring states of Bihar, Orissa and Bengal. The forest is mostly of tropical dry deciduous type receiving an annual rainfall below 1200 mm. Many economically important trees are found here: Shorea robusta (sal), Tectona grandis (teak), Dalbergia sissoo, Dendrocalamus strictus (bamboo), Acacia catechu (catechu), Emblica officinalis (Aonla), Aegle marmelos (Bel), Boswellia serrata (match-stick wood) and Diospyros melanoxylon (Biri patta) and D. ebony (ebony). These forests have extensive grass cover and assume savannah appearance particularly in dry seasons. Because of high density of villages around such forests leading to extensive grazing, lopping and collection of fuel-wood, much of these forests have degenerated into open savannahs, scrub savannahs or desert. In drier belts, the shrub jungles are dominated by Prosopis, Salvadora, Tecomella, Capparis aphylla, and Calotropis procera.

The natural sal-dominated forests of Uttar Pradesh and Bengal are of subtropical semi-evergreen type with a number of deciduous elements. A large area of natural forests has been replaced by the deciduous plantations of sal (Shorea robusta Gaertn), planted mainly through ‘taungya’ system*. As the planted sal ages, the associated vegetation also develops naturally and becomes species-rich. If left undisturbed, the plant community, developing in association with planted sal, fairly mimics the composition of the climax vegetation of natural-growth forest of the region. In addition to sal, a number of other plantations of fast growing trees have been tried, e.g., Tectona grandis on upland sites and Eugenia heyeanea, Trewia nudiflora, Terminalia arjuna and T. myricarpa on periodically inundated, lowland sites and Anthocephalus cadamba on lands bordering watershed areas. The left-over patches of natural-growth sal forests still show considerable species richness. Some of the large-tree genera are Terminalia, Ougenia, Dalbergia, Gmelina, Sclerocarya, Stereospermum, Adina, Mitragyna, Syzygium, Ehetra and Pongamia. The smaller trees, mostly occupying understorey, are the species of Bauhinia, Aegle, Mallotus, Cassia, Milialis, Semicarpus, Emblica, Oroxylum, Streblus and Woodfordia. A few massive lianas are Abrus precatorius, Acacia concina, Bauhinia vahlii, Caesalpinia bonducella Bridelia stipularis, Milletia sp., Mezoneurum cucullatum. Some of the species-rich genera which significantly contribute to the ground layer, especially in open forests, are: Desmodium, Cassia, Crotolaria and Moghania. The swampy sites usually grow Barringtonia acutangula and Calamus tenuis.

4. Central India

The region comprises mainly the Vindhyas (now included in Madhya Pradesh). It is a distinct vegetation unit on the granite and gneiss hills of 500-650 m altitude. Tectona and Madhuca are the dominant tree species. Species of Terminalia, Dipterocarpus, Boswellia, Buchanania, Lagerstroemia, Mangifera, Emblica, Anogeissus, Diospyros, Bauhinia, Butea and Woodfordia are some important common trees. The ground layer is mainly grassy with a number of legumes.

5. The West Coast of Malabar

It is the region of very heavy rainfall stretching from Cape Camorin in the south to parts of Gujarat in the north. The tropical evergreen rain forests with luxuriant vegetation are located in the south-western coast of Kerala, parts of Tamil Nadu and Karnataka and receive 2500 mm annual rainfall. The mixed deciduous or monsoon forests and subtropical or temperate forests are on the peninsular mountains. These climax formations have the richest diversity of flora and fauna. The trees are arranged in 4-5 layers (sinucae) of canopy, the top layer reaching upto 50 m with occasional emergent trees (or flag trees) which are still higher. Shrubs, epiphytes, lianas and ground flora make the forest quite impenetrable. Giant trees with large flanking buttresses are common e.g. Salmalia malabaricum and Lannea grandis. Dominant trees are Dipterocarpus grandiflorus, D. pilosa, D. indicus, Toona ciliata, Hopea odorata H. parviflora, Canarium strictum, Pterigota alata, Callophyllum alatum, Artocarpus hirsut, Vitex altissima and Hydnocarpus wightiana. Canopy is often covered with climber species of Ventilago, Pothos and Caesalpinia. There is a dense undergrowth of many ferns and shrubs.
The mixed deciduous or monsoon forests comprise species which remain leafless during December to June. They are composed of Terminalia tomentosa, T. paniculata, Tectona grandis, Dalbergia latifolia, Lagerstroemia lanceolata, Xylica xylocarpa, Adina cardifolia, Mitragyna parvifolia etc. The commonest bamboos are Bamboosa arundinacea and Dendrocalamus strictus.

The sub-tropical or temperate evergreen forests, commonly called as ‘Sholas’, which occur on a few hills above 1800m altitude. These forests are composed of Eurya japonica, Gordonia obtusa, Michelia nilgirica, Ternstroemia japonica, Eugenia, Ilex, Meliosma, Symplocos and various Lauraceae. The hill-tops carry extensive grasslands. Mangrove forests, grassland and dwarf forests also occur in this region. In the mangroves, Bruguiera, Sonneratia, Avicennia, Rhizophora etc. are common with Acanthus, a common shrub. Common grasses are Aristida, Heteropogon, Cymbopogon, Apluda, and Themeda.

The forests developed on red ferruginous clay and laterites at Mahabaleshwar, Matheran and Bhimshankar above 900 m elevation with rainfall about 5000 mm are evergreen forests comprising Eugenia, Actinodaphnae, Mangifera, Sideroxylon etc. Maemycelon is the commonest understorey species with Carvia callusa as undergrowth.

6. The Deccan

The Deccan including the major part of peninsular India is a hilly plateau with average rainfall of about 1000 mm. In the upper part the Satpura ranges have a thick forest of Hardwickia binata, Boswellia serrata, Tectona, numerous Acacias and a grassy undergrowth. The sandy and dry plains with low rainfall have open forests with Prosopis cinereria, Acacia leucocephala and A. latroneum. In rocky areas, with dry soil, Capparis and cactiform Euphorbia are present. Small tracks carry forests of Pterocarpus santalinus in the Cuddapoh and Hardwickia binata in Salem and north Arkot. The important sandal forests occur in this zone. Species of Anogeissus, Boswellia, Garuga, Buchnania, Dyospyros are common associates of teak in these forests on basalt. Quite similar species composition is met with on various hill ranges of peninsular India like Parasnath Hills (Chhota Nagpur), Mahendrgiri hills (south Orissa), Jashpur and Surguja hills (Madhya pradesh), Hills of Bihar, orissa and neighbouring states, Sholas (Nilgris, Palni and Annamalai), Malabar hills.

7. Assam

Assam comprises the valleys of the Brahmaputra and Surma with the hills of Khasi, Naga, Manipur and Lushai. The rainfall is very heavy above 2000 mm to even 10,000 mm (near Cherrapunjee). The vegetation is luxuriant, composed of Aesculus assamica, Artocarpus chaplasha, Shorea robusta, S. assamica, Dillenia pentagyna, Ferrmania colorata, Salmalia malabarica, Hydnocarpus kurzti. Michelia champaca, Ficus elastica, Mesua ferrea, Tetrameles spp. Vatica lanceaefolia, Alstonia scholaris, Pterygota alata, Morus laevigata and Stereospermum chelonoides. The very fast growing trees which occupy early successional open habitats are Sapium baccatum, Duabanga sonneratoides, Adina cardifolia, Anthocephalus cadamba with weed trees like Trema guineensis, Eurya japonica and Macranga denticulata.

The commonest bamboo is Dendrocalamus hamiltonii. The thick undergrowth is formed of canes, climbers and evergreen bushes. The hill forests of Assam are similar to those of the Eastern Himalayas with the exception that alpine zone is absent. These forests are dominated by Alnus nepalensis, Betula alnoides, Caprinus viminea, Rhododendron arboricum, Bucklandia populnea, Magnolia, Michelia, Prunus, Pyrus, and Acer spp. The pine forests are composed chiefly of Pinus keisya.

8. Andamans & Nicobar Islands

The Andaman forests may be classified into mangrove vegetation. Beach forests, evergreen, semi-evergreen and deciduous forests. The mangroves are swamp forests with Rhizophora sp. The beach forests have characteristic species of Mimusops, Calophyllum, Diperocarpus. The species of Terminalia and Lagerstroemia are common to both the deciduous and semi-evergreen forests.

9. Laccadive & Minicoy Islands

This group of islands along the western coast form a distinct botanical region which is very little known. Agathi island (hottest of Laccadive group) has a dense undergrowth with scattered coconut tree. In Androth island, there is luxuriant growth of ferns, there are Areca palm, tamarind and a few vines. In Suhelipos
island, the jungle has few coconut trees, Pandanus (screwpines) and Ficus benghalensis with Ipomea creepers.

10. Hill ranges of peninsular India

From the above account it appears that the Himalayan flora is absolutely distinct from other parts of India. The flora of some of the hills of Bihar, Orissa, Madhya Pradesh, Nilgiris and other regions in the peninsular India have attracted attention because they include a number of species common to Eastern and Western Himalayas and Western Ghats. The species are often in isolated patches on these hills. The main types are as follows:

a. Parasnath hills - The following species from the Parasnath hills of Chhota Nagpur plateau are distributed in the Himalayan region: Clematis natans, Thalictrum glyrophorum, Berberis asiatica and Geranium nepalense. The flora of these hills also resembles the flora of less elevated mountain ranges of central and south India. This relict flora is more or less allied to Kurseong of Darjeeling district.

b. Mahendra Giri hills - A number of plants that occur on these hills of South Orissa are common to Western and Eastern Himalayas and south Indian hill tracts. Some of these are: Indigofera cassioioides, Hamiltonia suaveolens, Viola patrinii, Peperomia reflexa and Carex speciosa.

c. Jaspur and Sarguja hills - The presence of one species each of genera, Crataegus, Pyrus and Berberis has been recorded at an altitude of 1200m on these hills of Madhya Pradesh. All these species are normally present in temperate Himalayas from Kashmir to Bhutan and eastern Himalayas.

d. Hills of Bihar, Orissa and neighbouring states - Thirteen species of Rosaceae, belonging to 7 genera have been recorded from these hills. Of these, Rubus ellipticus is the most widely distributed. The Rosaceae generally occur in the north temperate zone of Himalayas. Their presence in the hills of peninsular India indicates southward migration of Himalayan species during the recent past.

e. Nilgiri, Palnis and Annaimalai hills - The ‘Sholas’ of hill tops of these south Indian mountains have certain affinity with flora of Naga hills, Manipur, Khasi hills of Eastern Himalayas. These common species belong to genera like Hypericum, Ternstroemia, Eurya, Rhamnus, Berberis, Rhododendron, Meliosma, Thalictrum, Potentilla, Swertia and Gentiana. As a rule, not more than one species in a genus is common between the Himalayas and the southern hills which suggests a slow rate of migration which which to favour speciation.

f. Malabar hills - The flora of Kerala has a number of Malaysian elements belonging to families Clusiaceae, Dipterocarpaceae, Myristicaceae and many palms and bamboos. The Burmese genera such as Dipterocarpus, Grewia, Dioscorea and Gaultheria are found in this region.

g. Abor hills - The vegetation of Abor hills in the valley of Dihang and Brahmaputra rivers is interesting in that there is no pine in Abor land. There are several species of Quercus, Castanopsis, Betula and Englehardtia. The vegetation has strong Chinese affinity and many species are common to different hills of Meghalaya.

ORIGINS AND DISTRIBUTIONAL PATTERNS OF INDIAN FLORA AND FAUNA

According to Mani (1974) the flora and fauna that differentiated in the Peninsula were indeed the original flora and fauna of India. This complex arose from the ancient stock of Lemuria and the still older Gondwana floras and faunas. They were continuously distributed not only throughout the Peninsula but even up to the foot of newly rising Himalayas. It extended eastwards beyond the strict limits of India. The affinities of these taxa were mainly with Madagascar and South Africa; and to some extent with Australia and South America. The formation of the Assam gateway, through obliteration of Tethys sea (Fig.8), represents the most important phase in the bogeographical evolution of India. This gateway opened up the interchanges of flora and fauna between the peninsular and Assam-Burma areas. The Himalayan uplift dominates practically the entire range of events which shaped the climate and composition of flora and fauna of the whole India. The outstanding peculiarities of the present day distributional patterns are concentration and isolation of the dominant elements of flora and fauna in relatively small and widely
separated areas, resulting in more or less marked discontinuity. Altitudinal zonation is confined almost exclusively to the Himalayas but is nearly absent in Peninsula in spite of high elevations.

In certain genera the discontinuity may be extreme and may be marked by their occurrence in the Eastern Himalayas and or Assam and again only in Sri Lanka. In others, we find a series of more or less isolated patches of occurrence of the same species. There are numerous records of discontinuous distribution of different taxa.

Distribution pattern of some important Indian trees-

Puri et al. (1983) has given ten types of distribution pattern of important Indian trees-

1. More or less uniformly distributed trees- *Terminalia tomentosa, T. arjuna, Diospyros, Albizia, Acacia, Gmelina arborea, Adina cardifolia, Syzygium cumuni* (absent only from desert areas).

2. Discontinuously distributed trees over large part of India- *Lannea coromandelica, Tectona grandis, Eugenia ooejinensis, Bombax ceiba, careya arborea, Anogeissus latifolia, Hymenoducton excelsum*.

3. Trees showing discontinuous distribution in Western Ghats, Eastern Ghats, Assam and Burma- *Mesua ferrea, Xylia xylocarpa, Michelia champaca, Lagerostroemia flos-reginae*.


5. Forest trees showing discontinuous distribution in the eastern part of India- *Podocarpus nerifolia, Homalium tomentosum*

7. Forest trees showing discontinuous distribution in the Western Ghats, Eastern Ghats, Sri Lanka, Eastern India, Central India and parts of the western Himalayas- *Carrallia bracheata*, *Grewia tilifolia*, *Dillenia pentagyna*, *Toona ciliata*.

8. Trees distributed mainly in the Himalayas and extend to the eastern regions with a continuous or somewhat discontinuous distribution- *Betula alonoides*, *Ulmus wallichiana*, *Acer campbellii*, *A. oblongum*, *Engelhardtia spicata*, *Juglans regia*. *Bischofia javanica* may form a category of its own distribution, both in Assam, Burma, Western Himalayas and the Western Ghats.

9. Forest trees distributed in the Western Himalayas extending continuously or discontinuously to the Eastern Himalayas- The various conifers and *Dalbergia sissoo*.

10. Set of forest trees more widely distributed in whole of the country- *Diospyros*, *Acacia*, *Bombax*, *Boswellia*, *Albizzia*. (Except *Acacia* sps. They seem to avoid western desert region.

Theories to explain the discontinuous distribution of some Indian taxa

Various theories have been put forward to account for the discontinuous distribution of some Indian taxa-

A. *Himalayan Glaciation theory*

Medlicott and Blanford (1879) first suggested that the occurrence of Himalayan plants and animals on the higher ranges of southern India may be due to the retreat of the species towards the equator as a result of general lowering of atmospheric temperature during the Pleistocene period because of glaciation in the Himalayas. Subsequently, as the atmospheric temperature conditions became warmer, the plants and animals moved towards the higher parts of south Indian hills where they are now found.

Our knowledge of the Pleistocene glaciation is, however, limited to the Kashmir Himalayas. There are evidences to show that the Kashmir valley was warm and humid during Pleistocene and glacial movements have occurred in the Central and Eastern Himalayas. Accordingly cold climatic conditions occurred in the eastern parts of the Himalayas due to the presence of glaciers at lower altitudes. It pushed Himalayan flora southwards resulting into the discontinuity in distribution of tree species. This view is not supported well because the glacial period corresponded to a drier phase as much of the moisture was locked up in the ice.

Glaciation certainly changed the ecological conditions which influenced the factor responsible for the discontinuous distribution of Indian plants. As a result of freezing, during Ice Age, vast quantities of limestone was dissolved out from the Himalayas and reached down to plains, thus changing the fertility and mineral composition of the soils both in the hills and plains. It is probable that the plant species which have been growing on these limestone soils in the Himalayas, were able to migrate successfully through the plains to the south Indian hills where the conditions of the climate and the soil were probably similar to those of the Himalayan region during the Pleistocene. However, evidences are not enough in strong support of this theory.

B. *Southern Route Across the Indian Ocean theory*

This theory postulates the occurrence of a land connection or southern land-bridge route of migration across the Indian Ocean connecting India, Australia and New Zealand. Land connections do not seem to have occurred over the Bay of Bengal but across the Assam hills through the Vindhya-Satpura trend of mountains to the Western Ghats and then down south to Sri Lanka. It is guessed that plant migration in the past has occurred along these land routes. This theory may be used to explain the occurrence and discontinuity of some trees but it has not gained much ground.
C. Route across the Bay of Bengal theory

Interest in the ‘Southern Route Across the Indian Ocean Theory’ has been revived by Croizat (1968) and it is now considered that the migration could have occurred in the past through the Bay of Bengal route and the Indian Ocean had served as a link. Based on the observations of several workers, Croizat has suggested that the Bay of Bengal and its immediate southern approaches provided a major mode of biogeography involving tropical Africa, Asia, Malaysia and Australasia. He put his arguments with the help of information on the distribution of several animals and of plants like *Rhododendron*, *Erica* and others. He considers the Bay of Bengal as one of the foremost biogeographic units of the Far East, Malaysia, Australasia and Africa. Legris and Meher-Homji (1968) has brought out the importance of the Indo-Malaysian element in the humid vegetation types of north-east India and the west coast.

The theory of continental drift, however, does not support migration across the Bay of Bengal. Fig. 1 depicts the positions of India relative to Eurasia towards the end of Cretaceous, the end of Palaeocene and the end of Eocene. Accordingly, the contact of India with the Asian landmass took place towards the end of Palaeocene or early Eocene.

D. Deccan Trap theory

Towards the end of Cretaceous, western and central India were covered by large sheets of basic lavas. These formations are called Deccan Trap. The lower parts of the trap contain a few sedimentary beds laid down in lakes during the cool intervals. The discontinuous pattern of distribution of certain *Rhododendron* and *Festuca* species in Himalayas and on Nilgiris has been discussed by Meher-Homji (1967). He considered that in the geologic past, the Deccan plateau was elevated and that the climatic conditions, then, were such that many plant taxon had continuous distribution pattern in Indian sub-continent. Plants of Himalayan flora spread up to Nilgiris. With the passage of time Nilgiris hills were cut off as isolated parts on Deccan plateau which due to erosion, lost elevation. The climate of the plateau had very much changed due to their physiographic changes. The plants of Himalayan origin like *Rhododendron* spp. got entrapped on the Nilgiris and these plants could not survive in the intervening space (between Deccan plateau and Gangetic plain) due to the changed conditions.

E. Satpura Hypothesis

S.L. Hora (1944-51) put forward the Satpura hypothesis to account for the discontinuous distribution of certain fresh-water mountain-stream fishes between the eastern borderlands and southern block. He believed that the hill stream fishes characterized by torrential adaptations, now discontinuously distributed in the southern block and Assam hills, evolved primarily in the mountainous area of Yunnan and Indo-China and migrated as fully-evolved, torrential adapted fishes to the peninsula. The central idea of this hypothesis is that from Assam, the route of migration of these fishes to the south of the Peninsula, lay only westwards over the Satpura trend of mountains to the northern end of Western Ghats.

The Satpura hypothesis is based on the following suppositions-

1. In the geologic past the mountains of Satpura ranges of Vindhyas were united with Assam hills and Western Ghats. The *Tethys* sea area, however, formed a barrier between Himalayas and Assam hills (Fig. 8).
2. In the past the Vindhyas were approximately 2000 m in elevation. The present height resulted due to erosion
3. In the past the Himalayan ranges were connected with Sri Lanka through the Assam, Satpuras and Western Ghats’ chain of mountains and the rainfall was approximately 2500mm. All these mountains supported evergreen tropical forests.

According to this hypothesis, the ecological conditions during the past were somewhat similar to those of the wet Himalayan region and migration of plants and animals was possible from south to north or vice-versa. The connecting links between two mountain systems were the Assam hills (Khasi, Jaintia series, Parasnath hills) and Chhota Nagpur series. The fast flowing rapid streams on these ranges provided suitable conditions for fishes to migrate from the Himalayas to the Satpura streams.
The existence of a continuous Satpura range of hills has been questioned by many. The hills referred to this trend are composed of diverse stratigraphic units and Shillong plateau does not have any real connection to this trend. Further, there is no evidence of an uplift belt crossing the gap between Garo hills of Meghalaya and Rajmahal hills of extreme north-east corner of Peninsula since Gondwana times.

**F. Coromandel Route theory.**

This theory postulates that the migration of the floral elements from Assam to the Western Ghats has more probably been through Bengal, the hills of Orissa, the Easern Ghats, the Mysore plateau and the Nilgiris on climatic, geological, palaeobotanical and phytogeographical grounds. He discussed the distribution of *Dillenia pentagyna*. Legris and Meher-Homeji (1968) established 25 phytogeographic elements in the Indian flora and these phytogeographical elements have been evaluated for 21 vegetation types of peninsular India and Sri Lanka.

**G. Ecological Pockets theory**

According to Mani (1974) the origin of discontinuous distribution seems to be rather complex and is by no means an isolated event. The discontinuity is in some cases primary but in most cases it is secondary and derived and of relatively recent origin from a continuous distribution. The extensive and continuous ranges of a number of humid tropical forests have recently broken up into a series of isolated patches, because of topographical and climatic changes. In some groups, vast populations of the dominant genera have been decimated by man in the intervening areas, resulting in the present day discontinuity. On the basis of available biogeographical evidence it may be concluded that the same genera and species do indeed arise in widely separated areas. The most potent factor for the present day discontinuity is the persistent and large scale destruction of natural habitats and ecosystems by human activity nearly everywhere and quite often the effect goes beyond the critical point of natural recovery and stabilization. The reactions of any species affect all other species and the ecosystem as a whole.

The discontinuity must, therefore, be considered as impoverishment. Environmental deterioration and the impoverishment of flora and fauna are concomitant and interrelated effects of human interference. Where man has interfered least, the original flora-fauna complex largely survives. The concentration, isolation and discontinuity are all closely related peculiarities of biogeographical evolution of India. These and other peculiarities of the biogeography of India are closely correlated with its complex geomorphological evolution, the beginning of which may be traced back to the fragmentation of ancient Gondwanaland and the separation and rift of Peninsula from Madagascar. The gradual obliteration of the Tethys sea gave rise to uplift, folding and faulting of Himalayas. The gradual formation of Indo-Gangetic Plains by further filling up of the rift provided a direct contact between the oldest landmass and the youngest mountains, facilitating the movement of plant and animal life. Pleistocene glaciation on the Himalayas and the advent of man in India have also played a significant role (Fig. 9). However, there are many uncertainties and conjectural elements due to the lack of reliable palaeobotanical records.

Meher-Homji (1974) has also reviewed the problem of disjunct distribution with the help of some peculiar cases e.g., *Acacia planiformis, Capparis decidua* and *Albizia amara.*
Fig. 9. The evolution of the distributional patterns of plants and animals in India and the factors playing dominant role, mainly the series of events in continental-drift, the uplift of Himalaya and human influence. (After Mani, 1974; Ecology and Biogeography in India)
Other factors or causes affecting discontinuous distributions, are-

**a. Edaphic control** — The edaphic factors also intervene in explaining the distribution pattern. The edaphic controls could be exercised through the changes in moisture, pH, minerals, nitrogen, organic matter content and other factors. Gaps in the distribution can be created by the impoverishment of soil by erosion, sedimentation or deposition, making a locality unsuitable for regeneration of the existing species and providing better chances for the entry of other species. In Madhya Pradesh, sal and teak occupy two different well defined zones in the north-east and southwest regions respectively separated by an intervening zone of deciduous forests with the absence of teak and sal. Biotic factors like excess of trampling and overgrazing by cattle, lopping, girdling trees and seasonal fires result into deterioration of plant communities. The disjunction in the range of *Hardwickia binata* may be taken as example. Bioc-edaphic gaps in plain area gets flooded, thereby extending the discontinuity in the distribution of sal forests over much of the Siwaliks and adjoining Bhabar areas.

**b. Mosaic theory of regeneration**— As early as 1938, Auberville put forward his Mosaic or Cyclical theory of regeneration. He clearly recognized that the combination of species that dominates in a given small area, is not a permanent feature but variable both in space and time. The dominant trees of top canopy in a mixed forest vary from one spot to the other. These dominant trees are also likely to be replaced by others at the same spot over a long term period because the species which are common as seedlings and saplings are different from those forming the upper canopy dominants. On the basis of this theory, Auberville regards a forest block of the miscellaneous type as a mosaic, a patchwork of various combinations of dominant species, each patchwork being occupied by a different set of dominant species in a cyclical order.

Suggested Readings:


Mani, M.S. 1974 (edt.) *Ecology and Biogeography in India*. Dr W. Junk Publisher, the Hague.


Keywords: Phytogeography, Migration, Endemism, Continuous and discontinuous distribution, Indian vegetation, Eco-botanical regions, Distribution of Indian trees, Theories to explain discontinuous distribution.