SHRI CHHATRAPATI SHIVAJI COLLEGE OMERGA

Diveristy of Angiosperms- I

Notes for B. Sc. III (Botany) Paper XVI (A)

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Paper XVI (A) : Diversity of Angiosperms-I

Unit I

1. **Biodiversity :** Definition, concept, origin and evolution
2. **Types of biodiversity :** Species, genetic, ecological, cropland and agricultural diversity; biodiversity in India; endemism and hot spots; threatened species, threats to biodiversity
3. **Conservation of biodiversity :** Major causes for loss of biodiversity, listing of threatened biodiversity; Threatened categories – extinct, endangered, vulnerable, rare and indeterminate. Conservation measures: – ex-situ, and in-situ; biodiversity conservation in India.

Biodiversity

Introduction

The great variety of life forms on earth has developed since thousands of years. This diversity of living creates a support system for each civilization on the earth for its growth and development. Those that used this "bounty of nature" carefully and sustainably survived. Biological science has attempted to classify and categorize the diversity in nature for over a century. This information has helped a lot for understanding the process of 'development'.

However man has become consumerist, which has had a negative effect on the diversity of biological resources upon which it is based. The diversity of life on earth is so great that if we use it sustainably we can go on developing new products from biodiversity for many generations. This is only possible when we manage, maintain & treated 'biodiversity' as a precious resource and prevent the extinction of species.

What is biodiversity?

Biological diversity deals with the degree of nature's variance in the life forms. This variety can be studied at three levels; the genetic, Species and community, and the organization of species in an area into distinctive plant and animal communities constitutes ecosystem diversity.

'Biological diversity' or biodiversity is that part of nature which includes the differences in genes among the individuals of a species, the variety and richness of all the plant and animal species at different scales in space, locally, in a region, in the country and the world, and various types of ecosystems, both terrestrial and aquatic, within a defined area.

Origin & Evolution of Biodiversity

The origins of life on earth some three and a half billion years ago are obscure. Life was probably initiated as a product of organic reactions in the Earth's primordial seas. Alternative possibilities such as life beginning in muddy ooze, or of life having been seeded from outer space have also been suggested. Once life took hold on the planet, it began gradually to diversify. Unicellular unspecialized forms gradually evolved into complex multi-cellular plants and animals. Evolution is related to the ability of living organisms to adapt to changes in their environment. Thus the abiotic changes in nature such as climatic and atmospheric upheavals, repeated glaciations, continental drift and the formation of geographical barriers, segregated different communities of plants and animals and gradually lead to the formation of new species over millions of years.

Most species appear to have a life span extending over several million years. Their adaptability to gradual changes in their habitat, and interactions with newly formed species produce groups of inter linked organisms that continue to evolve together. Food chains, prey-predator relationships, parasitism (complete dependence on another species), commensalism (a partnership beneficial to both species), etc. are important examples. Behavioural patterns of the different species comprising a community of species link them to each other through their breeding biology, feeding patterns, migrations, etc. As ancient

species became extinct due to geological upheavals, they left behind empty 'niches' in the habitat that stimulated existing species to fill them through the formation of new species.

The Earth's ancient history has seen periods of mega extinctions, which have been followed by periods of formation of new species. Though these repeatedly led to a drastic 84 Environmental Studies for Undergraduate Courses reduction in the number of species, the diversity of life recuperated each time by gradually increasing the number of species existing on earth. This however took millions of years, as evolution is a very slow process. Thus when man came on the scene some 2 million years ago, the earth was more rich in species than ever before. During the recent past however, extinctions due to the activities of modern man have begun to take place so rapidly that nature has had no time to evolve new species. The earth is loosing species more rapidly than ever before. The diversity of life at all three organizational levels, genetic, species and ecosystem, is thus being rapidly modified by modern man. This is a reat loss to future generations who will follow us.

Types of Biodiversity

Species diversity

"The number of species of plants and animals that are present in a region constitutes its species diversity."

This diversity is seen both in natural ecosystems and in agricultural ecosystems. Some areas are richer in species than others. Natural undisturbed tropical forests have much greater species richness than plantations developed by the Forest Department for timber productions. A natural forest ecosystem provides a large number of non-wood products that local people depend on such as fruit, fuel wood, fodder, fiber, gum, resin and medicines. Timber plantations do not provide the large variety of goods that are essential for local consumption. In the long-term the economic sustainable returns from non-wood forest products is said to be greater than the returns from felling a forest for its timber. Thus the value of a natural forest, with all its species richness is much greater than a plantation.

Modern intensive agricultural ecosystems have a relatively lower diversity of crops than traditional agropastoral farming systems where multiple crops were planted. At present conservation scientists have been able to identify and categories about 1.8 million species on earth. However, many new species are being identified, especially in the flowering plants and insects. Areas that are rich in species diversity are called 'hotspots' of diversity. India is among the world's 15 nations that are exceptionally rich in species diversity.

Genetic diversity

"Every individual species either of plants or animals differs by its genetic makeup, this variety in genetic setup is known as Genetic Diversity".

This change is due to; large numbers of combinations are possible in the genetic setup, which expresses as specific characters. This genetic variability is essential for a healthy breeding population of a species. The diversity in wild species forms the '**gene pool**' from which our crops and domestic animals

have been developed over thousands of years. Today we are using this gene pool to create new varieties of more productive crops and to breed better domestic animals. Now modern Recombinant DNA technology can manipulate genes for developing better varieties of crops and domestic animals. Also it helps in production of various types of medicines and industrial products of human interest.

Genetic Species Diversity

Genetic species is 'the species which is developed due to modification/changes in chromosomal and genetic patterns by mutations and recombinations. It can also be called the 'origin of biological species'.

Organisms are always facing the changes in the environmental and ecological variations, and they modify it to adopt such changes, but apart from these, populations or species normally shows variations at their genetic level due to random mutations. This variation is shuffled from generations to generations by gene segregation and recombination.

Ecological / Ecosystem diversity

There are a large variety of different ecosystems on earth, which have their own complement of distinctive inter linked species based on the differences in the habitat. Ecosystem diversity can be described for a specific geographical region, or a political entity such as a country, a State or a taluka. Distinctive ecosystems include landscapes such as forests, grasslands, deserts, mountains, etc., as well as aquatic ecosystems such as rivers, lakes, and the sea. Each region also has man-modified areas such as farmland or grazing pastures. An ecosystem is referred to as 'natural' when it is relatively undisturbed by human activities or 'modified' when it is changed to other types of uses, such as farmland or urban areas. Ecosystems are most natural in wilderness areas. If natural ecosystems are overused or misused their productivity eventually decreases and they are then said to be degraded. India is exceptionally rich in its ecosystem diversity.

Cropland / Agricultural diversity

India is an important center of crop diversity. It is considered to be the house of 167 important cultivated plants species and 320 species of their wild relatives. India is also considered to be the center of origin for 30,000-50,000 varieties of Rice, pigeon pea, mango, turmeric, ginger, pepper, banana, coconut, cardamom, jack fruit, sugarcane, bamboo, taro, indigo, hemp, amaranths, gooseberries, etc.

If summarized, India has invented over 49,000 species of plants, which represents the 12% of the recorded worlds flora and 81,000 species of animals, which represents 6.67% of the faunal species recorded in the world. Endemism of Indian biodiversity is also significant and shows fairly high percentage 33% of the recorded flora of the world due to its habitat diversity and varied climatic conditions. All these facts mentioned above say that India is real representative of as Mega Diversity Centers of the World.

Biodiversity in India

India – Mega-Diversity Nation

India is located in South Asia between latitudes 6^0 and 38^0 N and longitudes 69^0 and 97^0 E. According to Hooker (1907) the flora of India is "more varied than any other country of equal area in the eastern hemisphere, if not in the globe". This is due to its geographical expanse and varied physical features, but also due to huge barriers such as the lofty Himalayas on the north and the Arabian Sea in the west and Indian Ocean on south. In spite of this the flora of India is dominated by the migratory elements, particularly from the Malaya, SE Asia, Europe, Africa, Arabia, Tibet, Burma, China and Japan.

Biodiversity of India

The Indian region is quite rich in biodiversity with 33% of endemic flora and sizable percentage of fauna. India is one of the **Twelve (12) Mega Diversity Nations** of the globe. The region is also a secondary center of diversity for grains, amaranths, maize, red pepper, soybean, potatoes and rubber plant. Its biological wealth is estimated to have over 48,000 plants species and 1,20,000 animal species. There is an abundance of wild varieties of crops, cereals, millets, pulses, spices, condiments, etc in India.

Biogeography is the branch of biology, which deals with the distribution of plants and animals in the present and past. It is therefore necessary for the student of biology to be familiar with the spatial relationships of the groups and their distributional patterns. It will appear that the primary cause of these changes can be attributed to physiological reaction of plants to ecological factors like climate. Climate is the most far reaching of the natural elements that controlling the life of an organism.

Indian sub-continent is characterized with the variety of climate types. For the study of flora the county has been divided into nine phytogeographical regions.

1) **Eastern Himalayas :** This is the most humid tract of the Himalayan ranges and includes Sikkim, Bhutan and the whole Arunachal Pradesh. The flora is disposed in three altitudinal regions: Tropical Temperate and Alpine. The trees of about 250 species belonging to different families dominate the tropical zone. Lower non-coniferous belt, upper coniferous belt and the highest *Rhododendron* belt dominate the temperate zone. The alpine zone is dominated by herbaceous species. Dominating fauna is Red panda, hog badgers, porcupines, goats, antelopes, etc.

2) **Western Himalayas :** This range includes Kashmir, the Punjab and the northern part of the Haryana, Himachal Pradesh and Uttar Pradesh. This belt does not represent the plants represented in the Eastern Himalayas. The climate is cooler and dryer. The chief dominant species are mostly herbaceous and many species common to the European flora. Dominating fauna is Wild ass, wild goats, antelopes, deer, golden eagle, snow leopard, wolf, fox, vultures, etc.

3) **The Indus Plain :** This part includes Punjab, Rajasthan and Gujarat and other regions of West of Aravali range. The climate is dry and the vegetation is dominated by the desert shrubs and herbs. The total species estimated are about 1500 belonging to 11 families. Grasses and legumes are most

dominant components. Dominating fauna is rodents, wild ass, black buck, desert cat, caracal, red fox, reptiles, camels, etc.

4) **The Gangetic Plain :** The entire plain stretching towards the eastern side from River Yamuna forms an Alluvium of the Ganga. It includes East and West Bengal and Bangladesh. The dominant species are mostly shrubs and trees. Dominating fauna is elephants, wild boar, deers, antelopes, wild dogs, panthers, tigers, lion, wild pigs, monkeys, jackals, gaur, etc.

5) **Assam :** This region receives heaviest rainfall, with Cherapunji as much as more than 1000cm. The temperature and wetness promotes the dense growth of tropical evergreen trees along with shrubby insectivorous plants and some conifers. Dominating fauna is elephants, sambar, nilgai, swamp deer, barking deer, tigers, panther, wild dogs, hyena, black bear, sloth bear, rhinos, etc.

6) **Central India :**It comprises Madhya Pradesh, Parts of Orissa and Gujrat. Forests developed in these regions are dominated by dry deciduous tree species and also shows thorny shrubs and bushes. Dominating fauna is Elephants, Deers, Nilgai, Barshinga, Leopards, Tigers, etc.

7) **Malabar :** A narrow strip of land west of Sahyadris extending from Bombay southwards being relatively more humid by receiving heavy precipitation. The evergreen as well as semi evergreen forests along the Sahyadris and coastal vegetation together have about 4000 species belonging to 150 families, dominated by tree species.

8) **The Deccan :** It includes Andhra Pradesh, Tamilnadu and Karnataka. This region is dry with 10cm rainfall. It shows the combination of dry deciduous species and tropical dry evergreen species like Sandal Forests. Trees and shrubs dominate this region. Dominating fauna is wild elephants, gaur, hoolock gibbon, golden languor, Loris, giant squirrel, civets, flying squirrels, nilgiri mongoose, etc.

9) **Andamans :** It has a wide range of spreading coastal vegetation like mangroves, beach forests with tall trees. These islands are dominated with trees, shrubs and herbs but now a days most of the area is clesred for paddy and sugarcane cultivation. Dominating fauna is bats, rats, reptiles, Andaman pigs, deers, pythons, white breasted swiftlet, sea eagle, tigers, etc

In flora, the country can boast of 45000 species, which accounts for 15% of the known world plants. Of the 16000 species of the flowering plants, 33% are endemic and located in the 26 endemic centers. Among the monocots, out of 588 genera in the country, 22 are strictly endemic. India is very rich in the faunal wealth and has nearly 75000 animal species, about 80% of which are insects. There are no clear estimated about marine biota but we can note that abundance of seaweeds, crustaceans, mollusks, corals, reptiles and mammals. It is estimated that almost one third of the animal varieties are found in Western Ghats of Kerala & Maharashtra only.

Recorded Biota of India

Category	Taxon	No. of Species	Category	Taxon	No. of Species
Flora	Bacteria	850	**Fauna** (Contd.)	Mollusks	5042
	Algae	2500		Echiura	33
	Fungi	23000		Annelids	1093
	Lichens	1600		Onychophora	1
	Bryophyta	2700		Arthropods	57525
	Pteridophyta	1022		Phoronida	3
	Gymnosperms	64		Bryozoan's	170
	Angiosperms	17000		Entoprocta	10
	Total	**48736**		Brachiopods	3
Fauna	Protozoan	2577		Chaetognatha	30
	Porifera	519		Echinodermata	765
	Cnidarians	237		Hemichordates	12
	Ctenophore	10		Protochordata	116
	Platyhelminthes	1622		Fishes	2546
	Nematodes	2350		Amphibians	204
	Rotifers	310		Reptiles	428
	Kinoryncha	10		Birds	1228
	Gastrotriches	88		Mammals	372
	Acanthocephalans	110		**Total**	**126188**
	Sipuncula	38			

Source : Kumar & Asija (2005) in Biodiversity Principles & Conservation

Hotspots of Biodiversity

Norman Meyers coined the term "Hotspots" in 1988. Hotspots are the areas where the rich abundance of plants and animals, but are threatened by human activities. Initially he listed all the tropical rain forests under this category but later on enlisted other parts of the world and number of hotspots reaches to twenty-five. Most hotspots are substantially endangered already having lost 3/4of their total original vegetation. Only terrestrial hotspots are identified but many remains to be accessed and identified in marine areas, especially coral reefs, which are thought to contain more than a million species living on less than 1% of the earth's surface.

Out of total 25 hotspots, nine (9) are in tropical rain forests, five (5) covers both dry and wet tropical forests, five (5) consists of temperate Mediterranean type of forests, six (6) includes tropical rain forests, dry forests and arid systems. About 75% of all estimated endangered and threatened animals live in these hotspots. Human induced environmental changes are constantly putting pressure on hotspots and therefore, conservation of biodiversity needs more attention due to changing trends. Biodiversity hotspots are losing number of species day by day due explosion of population, which leads to migration of the people in these areas.

Many organizations are now focusing on the protection of hotspots of the biodiversity and it results by giving better chance of survival for the species living in them. In 1989, Conservation International & McArther Foundation become first organization to adopt the concept of Biodiversity Hotspots as guiding principle for environmental conservation. Few new marine hotspots were identified in addition to 25 terrestrial hotspots and protection is extended to them as well.

List of Terrestrial Hotspots

1. Tropic of Islands	2. Meso-America	3. Caribbean
4. Atlantic Forest Region	5. Choco-Darlen Western Ecuador	6. Brazilian Carrado
7. Central Chillie	8. California Floristic Province	9. Madagascar & Indian Ocean Islands
10. Wallacea	11. Cape Floristic Province	12. Eastern Arctic's & Coastal Forests
13. Genuine Forests of W. Africa	14. Succulent Kamo	15. Mediterranean Basin
16. Sunderland	17. Philippines	18. Mountains of South Central China
19. Western Ghats & Srilanka	20. Indo-Burma	21. Caucasus 21. South West Australia
22. New Caledonia	23. Newzeland	25. Polynesia/Micronesia

Conservation of Biodiversity

Value of biodiversity

Environmental services from species and ecosystems are essential at global, regional and local levels. Production of oxygen, reducing carbon dioxide, maintaining the water cycle, protecting soil is important services. The world now acknowledges that the loss of biodiversity contributes to global climatic changes. Forests are the main mechanism for the conversion of carbon dioxide into carbon and oxygen. The loss of forest cover, coupled with the increasing release of carbon dioxide and other gases through industrialization contributes to the **'greenhouse effect'.** Global warming is melting ice caps, resulting in a rise in the sea level which will submerge the low lying areas in the world. It is causing major atmospheric changes, leading to increased temperatures, serious droughts in some areas and unexpected floods in other areas.

Biological diversity is also essential for preserving ecological processes, such as fixing and recycling of nutrients, soil formation, circulation and cleansing of air and water, global life support (plants absorb CO2, give out O2), maintaining the water balance within ecosystems, watershed protection, maintaining stream and river flows throughout the year, erosion control and local flood reduction. Food, clothing, housing, energy, medicines, are all resources that are directly or indirectly linked to the biological variety present in the biosphere. This is most obvious in the tribal communities who gather resources from the forest, or fisherfolk who catch fish in marine or freshwater ecosystems. For others, such as agricultural communities, biodiversity is used to grow their crops to suit the environment.

Urban communities generally use the greatest amount of goods and services, which are all indirectly drawn from natural ecosystems. It has become obvious that the preservation of biological

resources is essential for the well-being and the long-term survival of mankind. This diversity of living organisms which is present in the wilderness, as well as in our crops and livestock, plays a major role in human 'development'. The preservation of 'biodiversity' is therefore integral to any strategy that aims at improving the quality of human life.

Consumptive use value

The direct utilisation of timber, food, fuelwood, fodder by local communities. The biodiversity held in the ecosystem provides forest dwellers with all their daily needs, food, building material, fodder, medicines and a variety of other products. They know the qualities and different uses of wood from different species of trees, and collect a large number of local fruits, roots and plant material that they use as food, construction material or medicines. Fisherfolk are highly dependent on fish and know where and how to catch fish and other edible aquatic animals and plants.

Man and the Web of Life

The Biodiversity of an area influences every aspect of the lives of people who inhabit it. Their living space and their livelihoods depend on the type of ecosystem. Even people living in urban areas are dependent on the ecological services provided by the wilderness in the PAs. We frequently don't see this in everyday life as it is not necessarily overt. It is linked with every service that nature provides us. The quality of water we drink and use, the air we breathe, the soil on which our food grows are all influenced by a wide variety of living organisms both plants and animals and the ecosystem of which each species is linked with in nature. While it is well known that plant life removes carbon dioxide and releases the oxygen we breathe, it is less obvious that fungi, small soil invertebrates and even microbes are essential for plants to grow. That a natural forest maintains the water in the river after the monsoon, or that the absence of ants could destroy life on earth, are to be appreciated to understand how we are completely dependent on the living 'web of life' on earth.

The wilderness is an outcome of a long evolutionary process that has created an unimaginably large diversity of living species, their genetic differences and the various ecosystems on earth in which all living creatures live. This includes mankind as well. Think about this and we cannot but want to protect out earth's unique biodiversity. We are highly dependent on these living resources.

Productive use value: Marketable goods

Value of MFP>Timber (which is part of sustainable use). The biotechnologist uses biorich areas to 'prospect' and search for potential genetic properties in plants or animals that can be used to develop better varieties of crops that are used in farming and plantation programs or to develop better livestock. To the pharmacist, biological diversity is the raw material from which new drugs can be identified from plant or animal products. To industrialists, biodiversity is a rich store-house from which to develop new products. For the agricultural scientist the biodiversity in the wild relatives of crop plants is the basis for developing better crops.

Genetic diversity enables scientists and farmers to develop better crops and domestic animals through careful breeding. Originally this was done by selecting or pollinating crops artificially to get a

more productive or disease resistant strain. Today this is increasingly being done by genetic engineering, selecting genes from one plant and introducing them into another. New crop varieties (cultivars) are being developed using the genetic material found in wild relatives of crop plants through biotechnology. Even today, species of plants and animals are being constantly discovered in the wild. Thus these wild species are the building blocks for the betterment of human life and their loss is a great economic loss to mankind. Among the known species, only a tiny fraction have been investigated for their value in terms of food, or their medicinal or industrial potential.

Preservation of biodiversity has now become essential for industrial growth and economic development. A variety of industries such as pharmaceuticals are highly dependent on identifying compounds of great economic value from the wide variety of wild species of plants located in undisturbed natural forests. This is called ***biological prospecting***.

Social values

While traditional societies which had a small population and required less resources had preserved their biodiversity as a life supporting resource, modern man has rapidly depleted it even to the extent of leading to the irrecoverable loss due to extinction of several species. Thus apart from the local use or sale of products of biodiversity there is the social aspect in which more and more resources are used by affluent societies. The biodiversity has to a great extent been preserved by traditional societies that valued it as a resource and appreciated that its depletion would be a great loss to their society. The consumptive and productive value of biodiversity is closely linked to social concerns in traditional communities. 'Ecosystem people' value biodiversity as a part of their livelihood as well as through cultural and religious sentiments.

A great variety of crops have been cultivated in traditional agricultural systems and this permitted a wide range of produce to be grown and marketed throughout the year and acted as an insurance against the failure of one crop. In recent years farmers have begun to receive economic incentives to grow cash crops for national or international markets, rather than to supply local needs. This has resulted in local food shortages, unemployment (cash crops are usually mechanized), landlessness and increased vulnerability to drought and floods.

Commonly used modern drugs derived from plant sources: DRUG PLANT SOURCE USE

Atropine Belladonna Anticholinergic : reduces intestinal pain in diarrhoea .Bromelain Pineapple Controls tissue inflammation due to infection. Caffeine Tea, Coffee Stimulant of the central nervous system. Camphor Camphor tree Rebefacient: increases local blood supply. Cocaine Cocoa Analgesic and local anesthetic: reduces pain and prevents pain during surgery. Codeine Opium poppy Analgesic: reduces pain. Morphine Opium poppy Analgesic: controls pain. Colchicine Autumn crocus Anticancer agent. Digitoxin Common foxglove Cardiac stimulant used in heart diseases. Diosgenin Wild yams Source of female contraceptive: prevents pregnancy. L-Dopa Velvet bean Controls Parkinson's Disease which leads to jerky movements of the hands Ergotamine Smut-of-rye or ergot Control of haemorrhage and migraine headaches. Glaziovine ocotea glaziovii Antidepressant: Elevates mood of depressed patients. Gossypol Cotton Male contraceptive. Indicine N-oxide heliotropium indicum Anticancer agent. Menthol Mint Rubefacient: increases local blood supply and reduces pain on local application.

Monocrotaline Cotolaria sessiliflora Anticancer agent. Papain Papaya Dissolves excess protein and mucus, during digestion. Penicillin Penicillium fungi General antibiotic, skills bacteria and controls infection by various micro-organisms. Quinine Yellow cinochona Antimalarial. Reserpine Indian snakeroot Reduces high blood pressure. Scopolamine Thorn apple Sedative. Taxol Pacific yew Anticancer (ovarian). Vinblastine, Rosy periwinkle Anticancer agent: Controls cancer in children. vincristine (Vinca rosea) (Sadaphali) From: 'The Diversity of Life'; Edward O. Wilson (Norton Paperback. In association with Havard University Press – 1993)

Ethical and moral values

Ethical values related to biodiversity conservation are based on the importance of protecting all forms of life. All forms of life have the right to exist on earth. Man is only a small part of the Earth's great family of species. Don't plants and animals have an equal right to live and exist on our planet, which is like an inhabited spaceship? We do not know if life as we know it exists elsewhere in the universe. Do we have the right to destroy life forms or do we have a duty to protect them? Apart from the economic importance of conserving biodiversity, there are several cultural, moral and ethical values, which are associated with the sanctity of all forms of life. Indian civilization has over several generations preserved nature through local traditions. This has been an important part of the ancient philosophy of many of our cultures. We have in our country a large number of sacred groves or **'deorais'** preserved by tribal people in several States. These sacred groves around ancient sacred sites and temples act as gene banks of wild plants.

Aesthetic value

Knowledge and an appreciation of the presence of biodiversity for its own sake is another reason to preserve it. Quite apart from killing wildlife for food, it is important as a tourist attraction. Biodiversity is a beautiful and wonderful aspect of nature. Sit in a forest and listen to the birds. Watch a spider weave its complex web. Observe a fish feeding. It is magnificent and fascinating.

Symbols from wild species such as the lion of Hinduism, the elephant of Buddhism and deities such as Lord Ganesh, and the vehicles of several deities that are animals, have been venerated for thousands of years. Valmiki begins his epic story with a couplet on the unfortunate killing of a crane by a hunter. The 'Tulsi' has been placed at our doorsteps for centuries.

Option value

Keeping future possibilities open for their use is called option value. It is impossible to predict which of our species or traditional varieties of crops and domestic animals will be of great use in the future. To continue to improve cultivars and domestic livestock, we need to return to wild relatives of crop plants and animals. Thus the preservation of biodiversity must also include traditionally used strains already in existence in crops and domestic animals.

Major Causes for Loss of Biodiversity

The biodiversity in India i.e. Forests, Grasslands, Wetlands, Mountains, Deserts, Marine ecosystems, etc. face many pressures. One of the major causes of the biodiversity loss in India has been the depletion of vegetative cover in order to expand agriculture. Since most of the biodiversity rich forests also contain the maximum mineral wealth and also the best sites for water impoundment, mining and development projects in such areas have often led to destruction of habitats. Poaching and illegal trade of wild life products too have adversely affected biodiversity.

Every species has its importance in its ecosystem as wild plant or animal and it can provide new genetic material for improvement. Economically important plants were over exploited to meet the demand of growing population throughout the globe and resulted in the drastic decline in the size of their populations. Some species have already become extinct and there are many facing danger of extinction.

Many factors both natural and man-made have been responsible for limiting the distribution of and causing them to become rare or even extinct. Major causes of biodiversity losses are **development pressure** (construction, forest based industries, hydel/irrigation projects, mining, oil drilling, pollution, resource extraction and road and transport), **encroachment** (agriculture, expansion of forest villages, fishery, habitat depletion, horticulture, monoculture, forestry, new settlements, shifting cultivation, etc.), **exploitation** (collections made by scientists/institutions, firewood, food, trading for money, poaching, smuggling of timber/forest produce, medicinal plants, etc.)

Habitat Loss

High living standard and to accommodate an ever increasing human population, man has exploited and destroyed wildlife habitats. Loss, fragmentation or transformations of habitats have been mainly due to changes in land use such urbanization, industrialization, agricultural development, vegetation manipulation and shifting cultivation. Natural habitats such as forests, grasslands, deserts, wetlands, mangroves, coral reefs, etc are under tremendous pressure due to increasing population densities and activities of human beings. Wildlife habitats are getting destroyed at an alarming rate with disastrous effect on the biodiversity.

Since habitat requirement of most of the species are quite narrow, with the loss of suitable habitats, populations are destroyed eventually leading to extinction of species. Extinction rates are based on the relation between habitat loss and species loss indicates that regions rich in endemic species dominate the global patters of the extinction. But the overall rate of habitat loss is difficult to determine since statistics are limited only for the some habitats in few nations only.

Poaching

Poaching is an illegal exploitation of wild animals, which is unfortunately rampant in India even in the protected areas for precious animal products. India is the country where faunal diversity is remarkable due to which whites (British) attracted towards India to robber this wealth. Poaching of wildlife is done by the poachers for earning more money and by the tribals for their food, because of this many animal species are came under the endangered category and some are at the verge of extinction. Today is the situation that Govt. of India has developed many national parks, biospheres, eco-sensitive

zones, sanctuaries and projects to restrict the poaching activities by the civilians, smugglers, tribals, etc. in these areas. In India, for the conservation of endangered and threatened wild animals special projects are developed i.e. Tiger project, Gir Lion Project, Crocodile Breeding project, Rhinos Conservation Projects, Snow Leopard Projects, Project Elephant, etc.

In other view, many resources are utilized by illegal way that can also be called poaching. Plants are used since time immemorial for welfare of the community. But today ruthless killing/felling of trees for urbanization, industrialization, agriculture, etc is common thing. Plants also poached for their valuable products like essential oils, timber, tannins, resins, alkaloids, etc. As the plants forms first tropic level i.e. producers they play an important role in the ecosystem. If they are poached in such a quantity there will be imbalance of the ecosystem, which may leads into hazardous outputs. Thus, conservation of plant & animal diversity is must.

Man-Wildlife Conflicts

Nature always care for the associated systems which functional for development and multiplication of organisms living in the system. But due the development and changes in the life style of the human beings, a lot of pressure created on the natural systems and they are becoming unstable day by day. This situation is due to the disagreement between man and nature. Everything was in control till man was with nature, but suddenly we are facing natural calamities, imbalances of natural cycles and seasons as soon as we tried to overcome the nature. This has been created man-wildlife conflicts. Wildlife plays an important role in the ecosystems. They are at higher trophic levels such as secondary and tertiary consumer level. If they killed for the short-term benefits like money, definitely destruction of the ecosystems will be taken place.

A wildlife management practice clearly implies the influence and application of human manipulations. Even though this practice is rooted in human ethics, culture and legal aspects, it is still have to modify with the changing time because whatever the policies made to conserve the wildlife they have not been taken seriously by the people. People continuing the illegal activities like hunting, poaching, illegal trade, smuggling of forest produce, etc. This picture is due to the illiteracy about environment and ecology. Environmental educations can only the step to solve the conflict between man and nature.

Endangered & Endemic Species of India

Endangered Species

Endangered species are those, which are in danger of extinction and whose survival is unlikely due to drastic change or reduction in the habitats and seemed to in immediate danger of extinction. The Botanical Survey of India in its publication 'Red Data Book' has listed about 427 species of plants. This contributes to about 20% of India's total higher plants flora. The available evidences, however, indicate that human activities are eroding the biological recourses and greatly reducing the biodiversity. The Zoological Survey of India of also published the list of endangered plants, which includes primates (19), mammals (89), amphibians and reptiles (22), birds (38), etc. All these species needs a systematic management attention. List of Some Important endangered species form different regions is given below :

List of Endangered Species

Group	Name of the Region	Name of Species
Plants	Himalayas & E. India	*Abies devavai* (Pinaceae)
		Aconitum deinorthzum (Ranunculaceae)
		Adinandra griffithii (Theaceae)
		Anacolosa ilicoides (Oleaceae)
		Aphyllorchis Montana (Orchidaceae)
		Bortrichium virginianum (Ophioglossaceae)
		Cammelia cauduca (Theaceae)
		Captis teeta (Ranunculaceae)
		Cyathea gigantia (Cyatheaceae)
		Colchicum luteum (Liliaceae)
		Dendrobium densiflorum (Orchidaceae)
		Dioscorea deltoidea (Dioscoreaceae)
		Dischidia benghalensis (Asclepiadaceae)
		Drocera indica (Droceraceae)
		Elaeocarpus prunifolius (Elaeocarpaceae)
		Galiola lindleyana (Orchidaceae)
		Gentiana kurro (Gentianaceae)
		Lovatera kashmiriana (Malvaceae)
		Magnolia griffithii (Magnoliaceae)
		Nardostachis grandiflora (Valeriaceae)
		Nepanthes khasiana (Nepantheceae)
		Olax nana (Oleaceae)
		Podophyllum hexandrum (Podophyllaceae)
		Populus gambelii (Salicaceae)
		Raulvolfia serpentina (Apocyanaceae)
		Sapria himalayana (Rafflesiaceae)
		Vanda coerulea (Orchidaceae)
		Viola falconeri (Violaceae)
		Zanthozyllum scandens (Vitaceae)
	Peninsular India	*Apama barberi* (Aristolochiaceae)
		Bentinkia condaponna (Arecaceae)
		Ceropegia fantastica (Asclepiadaceae)
		Dioscorea wightii (Dioscoreaceae)
		Frerea Indica (Asclepiadaceae)
		Gnetum ula (Gnetaceae)
		Hoya wightii (Asclepiadaceae)
		Lobelia nicotianifolia (Lobeliaceae)
		Monisurious devegrens (Poaceae)

		Piper berberi (Piperaceae)
		Pterocarpus santalinus (Pterocarpaceae)
		Santalum album (Santalaceae)
	Rajasthan & Gujarat	*Commifora weightii* (Burseraceae)
		Helichrysum cutechicum (Asteraceae)
		Hyphaene dichotoma (Arecaceae)
		Rosa involuchrata (Rosaceae)
		Saussarea bractiata (Asteraceae)
	Gangetic Plain	*Aldrovanda vesiculosa* (Droceraceae)
	Maharashtra	*Andrographis paniculata* (Acantheceae)
		Amorphophallus commutatus (Areceae)
		Cassia tomentosa (Caesalpiniaceae)
		Ceropegia occulata (Asclepiadaceae)
		Habenaria digitata (Orchidaceae)
		Peristylus constrictus (Orchidaceae)
		Theriophonum minutum (Arecaeae)
	Andaman & Nicobar	*Ailanthus kurzii* (Simaroubaceae)
		Conarium mannii (Burseraceae)
		Lagerstromoea hypoleuca (Lytheraceae)
		Myristica andamanica (Myristicaceae)
		Podocarpus neriifolius (Podocarpaceae)
		Psilotum campanulatum (Psilotaceae)
		Uvaria nicobarica (Annonaceae)
Animals	**Mammals**	Andaman wild pig *(Sus scrofa)*
		Bison or Gaur *(Bos gaurus)*
		Blue whale *(Balaenoptera musculus)*
		Cheetah *(Acinonyx jubatus)*
		Chital *(Axis axis)*
		Desrt cat *(Felis lybica)*
		Four horned antelope *(Tetraceros quadricornis)*
		Golden languor *(Presbytis geei)*
		Hyaena *(Hyaena hyaena)*
		Indian elephant *(Elephas maximus)*
		Panther *(Panthera paradus)*
		Red fox *(Vulpes vulpes)*
		Sloath bear *(Melursus ursinus)*
		Tiger *(Panthera tigris)*
		Wild dog *(Cuon ulpinus)*
	Amphibians & Reptiles	Agra monitor lizard *(Varanus grisus)*
		Crocodile *(Crocodilus palustris)*
		Green sea turtle *(Chelonia mydas)*
		Pythons (All Spp. Of *Python*)
		Toads *(Nectophyrenoides spp.)*

		Water lizard *(Varanus salvator)*
	Birds	Andaman teal *(Anas gibbrifroans albogularis)*
		Black necked crane *(Grus nigricollis)*
		Comb duck *(Sarkidiornis melanotos)*
		Hornbills *(Aceros nepalensis)*
		Indian Pied Hornbill *(Anthracoceros malabaricus)*
		Large falcons *(Falco perigrinus)*
		Mountain quill *(Ophrysia superciliosa)*
		Nicobar megapod *(Caloenas nicobarica pelewensis)*
		Peafowl *(Pavo cristatus)*
		Spur fowl *(Gallaperdix spp.)*
		White bellied sae eagle *(Haleetus leucogaster)*
		White spoonbill *(Platalaea leucorodea)*
		White winged wood duck *(Cairina scutulata)*

Endemic Species

Endemic species are the plants, which are limited in their distribution i.e. they are restricted to a small area and not found elsewhere in the world. This may due to 1) poor adaptability of a species 2) presence of some ecological barrier due to which migration of seed or spores could not taken place (Mountains, seas, oceans, etc.) 3) the species might have been young and not have enough time to spread.

Endemism of Indian biodiversity is significant. About 4900 species of flowering plants are 33% of the recorded floras are endemic to the country. These are concentrated in the floristically rich areas of North East India, the Western Ghats, North West Himalayas and the Andaman and Nicobar Islands. *Sequoia* (red wood), *Matasequoia* of N. America, *Ginkgo* of China, *Manglietia*, *Talauma* of SE Asia, *Degeneria* of Fiji islands are some examples of endemic species. Some Indian endemics are *Pteridium aquilinum* (Pteridaceae), *Solanum nigrum* (Solanaceae), *Podophyllum* spp. (Ranunculaceae), *Platanus* spp. (Platanaceae), *Senecio* spp. (Asteraceae), *Scirpus lacustris* and *S. tabernemontanii* (Cyperaceae), etc.

It is estimated that 62% of the known amphibian species are endemic to India of which a majority occur in Western Ghats, higher vertebrates shows 396 species, Indian mammals 44 species, reptilian endemic shows 187 species, 110 species of amphibians, and birds shows 55 species confined to within Indian territorial limits. Faunal endemic species are Lion tailed Macaque *(Macaca silenus)*, Nilgiri leaf monkey *(Trachypitheous johni)*, Brown palm civet *(Paradoxurus jerdoni)*, Nilgiri thar *(Himitragus hylocrious)*

Threatened Categories

Summary of 2006 IUCN Red List categories.

Species are classified by the IUCN Red List into nine groups, set through criteria such as rate of decline, population size, area of geographic distribution, and degree of population and distribution fragmentation.

- **Extinct** (EX) – No known individuals remaining.
- **Extinct in the Wild** (EW) – Known only to survive in captivity, or as a naturalized population outside its historic range.
- **Critically Endangered** (CR) – Extremely high risk of extinction in the wild.
- **Endangered** (EN) – High risk of extinction in the wild.
- **Vulnerable** (VU) – High risk of endangerment in the wild.
- **Near Threatened** (NT) – Likely to become endangered in the near future.
- **Least Concern** (LC) – Lowest risk. Does not qualify for a more at risk category.Widespread and abundant taxa are included in this category.
- Data Deficient (DD) – Not enough data to make an assessment of its risk ofextinction.
- Not Evaluated (NE) – Has not yet been evaluated against the criteria.

When discussing the IUCN Red List, the official term "threatened" is a grouping of three categories: Critically Endangered, Endangered, and Vulnerable.

In-situ And *Ex-Situ*Conservation

In-situ conservation

Biodiversity at all its levels, genetic species and as intact ecosystems can be best preserved *in situ* by setting aside an adequate representation of wilderness as 'Protected Areas'. These should consist of a network of National Parks and Wildlife Sanctuaries with each distinctive ecosystem included in the network. Such a network would preserve the total diversity of life of a region. In the past National Parks and Sanctuaries in India were notified to preserve major wildlife species such as tigers, lions, elephants, and deer. The objective of these areas should be expanded to the preservation of relatively intact natural ecosystems, where biological diversity – from microscopic unicellular plants and animals, to the giant trees and major mammals – can all be preserved.

Project Tiger:

Project Tiger was launched by the Government of India with the support of WWF-International in 1973 and was the first such initiative aimed at protecting this key species and all its habitats.

Project Tiger was initiated in nine Tiger Reserves in different ecosystems of the country covering an area of 16339 sq km. By 2001 the number of Tiger Reserves increased to 27, covering an area of 37761 sq km. The tiger count climbed from 268 in 1972 in the nine Tiger Reserves, to around 1500 in 1997 in the 23 Tiger Reserves. The Project tiger recognized the fact that tigers cannot be protected in isolation, and that to protect the tiger, its habitat needed to be protected.

Crocodile Conservation:

Crocodiles have been threatened as their skin is used for making leather articles. This led to the near extinction of crocodiles in the wild in the 1960s in India.

A Crocodile Breeding and Conservation Program was initiated in 1975 to protect the remaining population of crocodilians in their natural habitat and by creating breeding centers. It is perhaps one of the most successful ex situ conservation breeding projects in the country.

Crocodiles have been extensively bred in over 30 captive breeding centers, zoos and other sites where successful breeding takes place. Thousands of crocodiles of all three species have been bred and restocked in 20 natural water bodies. However species cannot be protected individually as they are all inter dependent on each other.

Thus the whole ecosystem must be protected. The biologist's view point deals with areas that are relatively species rich, or those where rare, threatened or endangered species are found, or those with 'endemic' species which are not found elsewhere. As rare endemic species are found only in a small area these easily become extinct due to human activity. Such areas must be given an added importance as their biodiversity is a special feature of the region.

Animals such as elephants require different types of habitat to feed in during different seasons. They utilize open grasslands after the rains when the young grass shoots are highly nutritious. As the grasses dry, the elephants move into the forest to feed on foliage from the trees. A Protected Area that is meant to protect elephants must therefore be large enough and include diverse habitat types to support a complete complement of inter linked species.

Wildlife Sanctuaries and National Parks of India:

There are 589 Protected Areas in India of which 89 are National Parks and 500 are Wildlife Sanctuaries. They include a variety of ecosystems and habitats. Some have been created in order to protect highly endangered species of wild plants and animals found nowhere else in the world.

The Great Himalayan National Park is the largest sanctuary in this ecosystem and is one of the last homes of the beautiful snow leopard.

Dachigam Sanctuary is the only place where the rare Hangul or Kashmir stag is found. There are several Sanctuaries in the Terai region, **Kaziranga National Park** is the most famous which has elephant, wild buffalo, gaur, wild boar, swamp deer, and hog deer, in large numbers, as well as tiger and leopard. Its bird life is extremely rich and includes ducks, geese, pelicans and storks.

The **Manas Sanctuary**, in addition to the above Terai species, also includes the rare golden langur and the very rare pygmy hog, the smallest wild boar in the world. The florican is found only in a few undisturbed grasslands in the Terai sanctuaries.

In the sal forests of Madhya Pradesh, there are several Protected Areas.

Kanha offers a wonderful opportunity to observe wild tigers from elephant back. It is the only Protected Area in which a sub species of the Barasingha is found.

Bharatpur is one of the most famous water bird sanctuaries in the world. Thousands of ducks, geese, herons, and other wading birds can be seen here. This is the only home of the very rare Siberian crane which migrates to India every winter. During the last 20 years, the 30 or 40 Siberian cranes have dwindled to only 2 or 3. During 2002-3 no cranes were seen and it is possible that this beautiful bird will never again come to India.

In the Thar desert, the wild life is protected in the **Desert National Park.** Here large numbers of black buck, neelgai and chinkara can be seen. The Great Indian Bustard lives in these arid lands.

Ranthambor was the most well-known sanctuary for observing tigers in the wild till about 3 or 4 years ago. Since then many tigers have been killed by poachers.

Project Elephant: Project Elephant was launched in 1992 to ensure the long-term survival of a viable population of elephants in their natural habitats in north and northeastern India and south India. It is being implemented in 12 States. In spite of this, our elephant herds are at threat as their habitat is shrinking and their migration routes are disrupted by human activities.

The **Great and the Little Rann of Kutch** have been made into sanctuaries to protect the very rare wild ass, the flamingo, the star tortoise and the desert fox.

In Gujarat, the **Gir Sanctuary** protects the last population of the majestic Asiatic lion. This thorn and deciduous forest is also the home of large herds of chital, sambhar, and nilgai. The sanctuaries of the Western Ghats and associated hill ranges protect some of the most diverse forest types in the country. The few examples of highly threatened species include the Malabar giant squirrel, the flying squirrel and a variety of hill birds, several species of amphibians, reptiles and insects. These regions are also rich in highly endemic plant life.

Sanctuaries such as **Bhimashankar, Koyana, Chandoli and Radhanagari** preserve this rich flora in Maharashtra, **Bandipur, Bhadra, Dandeli, Nagarhole,** etc. in Karnataka, and **Eraviculum, Perambiculum, Periyar, Silent Valley**, in Kerala.

In the Nilgiri Hills the rich forest Sanctuaries protect some of the last pockets of the Indian elephant in South India. Examples include **Bandipur, Madhumalai, Wynad** and **Bhadra.** During the last 10 years, a large number of the great tusker elephants of this region have been ruthlessly killed for their ivory. Now very few of these magnificent animals are left in these jungles.

Two important sanctuaries meant for preservation of coastal ecosystems are the **Chilka Lake** and **Point Calimere.** The **Sunderbans** protect the largest mangrove delta in India. The **Marine National Park** in Gujarat protects shallow areas in the sea, islands, coral reefs and extensive mudflats. Over a hundred Protected Areas have been created in the Andaman and Nicobar Islands to preserve their very special island ecosystems.

Phytotaxonomy

Classification of Angiosperms

Keeping the things arranged is a basic human instinct. Laboratories, libraries workshops, shops etc are easier to work in if there is a system to keep track of things. Biology is no exception. It is lot easier to study living things if we have a system that keep something apart from other things. Biologists called this system as classification or taxonomy. Typically, classification can be defined as the systematic arrangement of similar organisms into categories on the basis of their structural or evolutionary relationships.

The naming and classification of plants undoubtedly began in the earliest stages of civilization. Our own observations show that plants are of many kinds, and we immediately seek for a name to apply to a plant of interest. The primitive people and tribal communities of today, as well in the past, apply common names to those plants that are peculiar or that affect their life in any way. Early classification systems were utilitarian; plants were grouped as to whether they were beneficial or harmful.

With increasing civilization, especially as knowledge grew concerning the uses of plants in food and medicine, the necessity of plant names became even greater. And ultimately, as the number of known plants increased and as botanists collected plants from far corners of the earth, it became necessary to group plants into large categories following rational principles. The collection, naming and classification of plants nowadays are carried out mainly with the objective of showing their origins and relationship, and also to provide positive identification for the hundreds of thousands of different kinds of plants.

Kinds of Classification

According to the principle employed, mainly three kinds of classifications are recognized. They are: Artificial, Natural and Phylogenetic. In practice, these may overlap.

Artificial Classification is based on convenient or conspicuous diagnostic characters without attention to characters indicating relationship; often a classification based on a single arbitrarily chosen character such as flower colour, habit, habitat, time of flowering or arrangement of leaves, rather than an evaluation of the totality of characters. The earlier pre-Darwinian systems of classification were largely artificial.

Linnaeus' sexual system, which is based on the number of stamen and pistils, falls in this category since unrelated plants can have same number of stamen and pistils in their flowers.

Natural Classification is one which is based on over-all resemblances in external morphology, and unlike artificial systems, involved as many characters as possible. It is presumed that the larger the number of characters shared by different plants, more closely are they related to each other. Overall gathering data from diverse disciplines like palynology, embryology, anatomy, phytochemistry, cytology etc, and not the morphology alone nowadays ascertain similarity. Later pre-Darwinian systems, which were based on over-all resemblances in gross morphology, were mostly natural.

Phylogenetic Classification is based on hypothesized evolutionary relationship. In the years, following Darwin's Origin of Species (1859) the theory of evolution gradually replaced the concept of special creation of species. It was found that species are not fixed or unchanging, but have evolved from pre-existing species during geological time. It is now considered that, in general, similarities in structure are evidences of evolutionary relationship. Thus have arisen modern phylogenetic systems of classification based on relationship by descent. Such systems utilize previously determined natural groups, and categories – genera, family, orders – of the natural systems are arranged in scheme that presumably reflects evolutionary relationships. Since 1980's phylogenetic classification has been made much more facile by using molecular data. Data from many sources are used to determine relationship. Thus any phylogenetic scheme of plant classification is subject to change as our knowledge of the various groups increased.

History and Development

In order to understand the field of taxonomy or classification at the present day, it is necessary to have some knowledge of the history of the subject and the development of the ideas associated with it. The observations made by the earlier workers were never wasted; subsequent workers with some modifications incorporated them into classifications. Scientists have struggled to find correct classification systems to use. They have eventually agreed on the systems we use today.

The discipline of plant classification has extremely deep cultural roots in all parts of the world. Ancient men who made their living by gathering food from the wild were probably much more familiar with the local plants, in terms of species recognition, than most people today. Though several cultural groups like African, Asian and Native American carried a wealth of botanical information into modern times, present systems of angiosperm classification have been derived from a European base. Historical development of classification is briefly reviewed here.

The Ancients

Theophrastus **(370 – 285 B.C.)**. He was a Greek philosopher and is regarded as the "Father of Botany". He was born in the city of Eresus. A people of Plato, and later a people and assistant to Aristotle, he embodied to the full extent the culture and learning of ancient Greece. For most of his life he lived in the midst of Lyceum botanical garden, established by Aristotle at Athens, and there he taught and wrote books representing many fields of knowledge. Theophrastus covered most aspects of botany: description of plants, distribution, classification, propagation, germination and cultivation. He is accredited with

more than 200 publications; only few of his writings survive today. His two important botanical works "**Inquiry into Plants**" and "**The causes of Plants**" provided a systematic treatment of over 500 species according to habit (herbs, under-shrubs, shrubs and trees) and separated according to flowering and non-flowering. He recognized and described families among flowering plants, such as carrot family, known today as Umbelliferae (Apiaceae). He recognized genera, in the sense of a group of species, and applied to them Greek names then in use. A few generic names currently in use, such as *Daucas*, *Asperagus*, *Anemone*, and *Narcissus*, originated during his time.

Dioscorides (Ist century A.D.) was a Greek physician in Roman army. His most famous work was De Materia Medica, *which discussed the medicinal qualities of 600 plants. This included natural grouping of species that represent well-defined modern families (Apiaceae, Fabaceae, Lamiaceae). The plant descriptions in his* De Materia Medica *were adequate for identification, including methods of preparation, medicinal uses, and doses. His work was used in various translations and editions for next 1000 years.*

The Middle or Dark Ages

The period from the fall of the Rome to the Renaissance is often called dark ages because of intellectual stagnation. Very little original botanical work was done during this period. Most workers copied and translated the ancient work of Greeks and Roman.

Alburtus Magnus **(1193-1280 A.D.)** was only botanist of note during this period. His contemporaries popularly called him "Doctor Universalis". In his work *De Vegetabilis* he is believed to have first differentiated monocots from dicots.

Renaissance, the Herbalists and Transition Period

The renaissance in Europe that started in the 14th century marked the beginning of an active period in which artistic, social, scientific, and political thoughts turned into new directions. Two major technological innovations – printing press and science of navigation – contributed to renaissance and especially to plant taxonomy. With the invention of printing press in 1440, many large volumes about plants and their medicinal uses, known as herbals, were produced throughout Europe. The authors of these books (herbals) are known as 'herbalists'. It helped making knowledge available about the practical uses of plants, primarily from medicinal standpoint, to all. Herbalists did not propose any original systems of classification but marked the period of original work rather than copying the ancient work. Navigation made explorations easy and the collection of new species from ongoing explorations forced the herbalist to extend the initial efforts of the ancients to structure and order flowering plant diversity. Many natural and well-defined genera and families were established during this period. Prominent herbalists and their works are:

Otto Brunfels	*(1464-1534). German Herbalist.* Herbarium Vivae Eicones.
Gerome Bock	(1469-1554). German. *Neu Kreuterbuch.*
Leonhard Fuchs	(1501-1556). German. *De Historia Stirpiu, New* Kreuterbuch.
John Gerard	(1542-1612). English. *The Herball*,or, *Generall Historie of Plantes.*

Rombert Dodoens (1517-1585). Flemish. *Cruydeboeck.*

Herbalists advanced science of botany but systems adopted by herbalists although commendable in their own way, had very little systematic basis. It was from the sixteenth and seventeenth century onwards that attempts were made to study more and plants and a large number of characters in order to arrive at a satisfactory classification. Some of the 16th and 17th century botanists are:

Andrea Caesalpino(1519-1603), an Italian, tried to base his classification on logic rather than utilitarian concept. He published *De Plantis* in 1583, which contain description of about 1500 plants. This was the first methodical classification of plants based on definite morphological criteria. Caesalpino recognized the usefulness of fruits and seeds in classification. His views influenced the later botanists like Tournefort, John Ray and Linnaeus.

***Casper Bauhin* (1560-1624).** A Swiss botanist; published *Pinax theatri botnici* in which he listed 6000 plants. He also provided synonymy i.e. the other names used for a species by earlier workers and binomials for many plants that he named. Bauhin is credited with modern concept of genera and species.

John Ray (1628-1705), a British botanist and philosopher formulated the principle that all parts of the plant should be used for classification- a principle now recognized as the corner stone of a natural system. His system of classification is presented in his *Methodus Plantarum* (1703), which contain description of 18000 species of plants. He grouped plants by their resemblance to one another and divided the plant kingdom into herbs and trees and further divided herbs into imperpectae (flowerless) and perfactae (flowering plants). Flowering plants and trees were further divided into dicotyledons and monocotyledons.

***J.P. de Tournefort* (1656-1708).** French botanist produced a classification that was purely artificial (based on few features). He is regarded as the "father of genus concept". In his publication *Institutiones Rei Herbarie* (1700) he provided descriptions for 698 genera. He differentiated genera on the basis of floral and vegetative characters. Linnaeus later adopted most of the Tournefort's genera that were distinguished by floral characters. The systems based on habit and the pre-Linnaean era ends with the system of Tournefort.

The Sexual or Artificial System

The botanical research on the European flora and subsequent explorations resulted in the collection of more and more plants by the eighteenth century that required a simple and efficient system of naming and classification. This demand produced several purely artificial systems of which Linnaeus' sexual system is most important

Carolus Linnaeus (1707-1778). It is to Swedish botanist, Carolous Linnaeus, that we owe the modern methods of naming plants. He is considered as "Father of Taxonomy". Before the time of Linnaeus it was the general custom to name plants with a single name followed by a set of descriptive nouns and adjectives (polynomials). Linnaeus established what has come to known as 'binomial system' of nomenclature, which involves naming of plants by two names – one for the genus and one for the species.

In addition to establishing the practice of binomial nomenclature, Linnaeus also set up a system of classification that was more comprehensive than any previously devised. This system is usually called as 'sexual system' or 'artificial system', because Linnaeus based his classification on number of stamens and their relation to one another and to other floral parts. Linnaeus divided plants into 24 classes, of which 23 were of flowering plants and the 24th class includes non-flowering plants i.e. ferns, mosses, fungi and algae. While the artificial approach allowed quick sorting and identification, its application produced unnatural grouping. The important publications of Linnaeus are: *Syatema Naturae*(1735), *Genera Plantarum*(1737) and *Species Plantarum*(1753). Because of the consistent use of binomial nomenclature, the date of publication of his *Species Plantarum* (Ist May, 1753) is considered as a starting point of the modern botanical nomenclature.

The system of Linnaeus was very simple and convenient and remained in force until the beginning of the 19th century.

Natural Systems of Classification

The wealth of plant material collected by the botanist world over during eighteenth century could not be satisfactorily identified with the help of Linnaeus' sexual system and a need was realized for a more objective classification. This resulted in the development of still better systems (based on overall resemblance in external morphology), which, unlike artificial systems, involved as many characters as possible.

Michel Adanson(1727-1806), a French botanist, published a two volume work *Familles des Plantes* (1763). He recognized 58 natural orders according the their natural affinities. He based his classification on using as many characters as possible and giving equal weightage to all the observable characters. This is precursor of modern computer aided Numerical Taxonomy, which is often called Adansonian Taxonomy.

Antonie Laurent de Jussieu(1748-1836), a French botanist published his system in *Genera Plantarum* (1789) incorporating his uncle's (Bernard de Jussieu, 1669-1776) work along with his own. He laid emphasis on number of cotyledons, presence or absence of petals and position of the stamens with respect to the ovary.

Augustin Pyrame de Candolle(1778-1841), a Swiss botanist, published his views on classification in his work *Theorie Elementaire de la Botanique*(1813) and introduced the term **Taxonomy** do designate the theory of plant classification. He was first to use the characteristics of vascular tissues in the classification of plants and recognized two major groups - Vasculares (Vascular bundle present) and Cellulares (no vascular bundle).

George Bentham(1800-1884) and ***Sir J.D. Hooker***(1817-1911). These two English botanists associated with Royal Botanic Gardens, Kew, presented the most elaborate natural system of classification in their three-volume work *Genera Plantarum* (1862-83). This was a major landmark in botany, for its system as well as for its quality. All genera of seed plants then known were very carefully and accurately described in Latin observing living specimens or dissected herbarium material. The geographical distribution of

each genus was given. They followed de Candolle's system with some modifications. The *Genera Plantarum* provided the classification of seed plants, including gymnosperms, describing 200 orders (equivalent to present day families) and 7569 genera. The larger genera were further divided into subgenera and sections. They estimated the seed plant to include 97,205 species. This was the last great work produced on the assumption that angiosperm taxa are fixed entities, unchanging through time and placed on earth by God. British and Indian herbaria are still arranged following the system of Bentham and Hooker.

Bentham and Hooker divided seed plants into three classes (Dicotyledones, Gymnosperms and Monocotyledones), three sub-classes, 21 series, 25 cohorts and 202 orders (initially 200 orders). Orders Vochysiaceae and Cyrillae were incorporated later.

OUTLINE OF SYSTEM OF BENTHAM AND HOOKER, 1862-1883

I. CLASS: DICOTYLEDONES (two cotyledones, exogenous growth)

Sub class 1. POLYPETALAE (petals separate)

Series I. Thalamiflorae (Petals and stamens hypogynous and usually many)

Cohort 1. Ranales (Gynoecium apocarpus)

Orders: 1, Ranunculaceae; 2, Dilleniaceae; 3, Calycanthaceae; 4, Magnoliaceae; 5, Annonaceae; 6, Menispermaceae; 7, Berbaridaceae; 8, Nymphaeaceae

Cohort 2. Parietales (Parietal placentation)

Orders: 9, Sarraceniaceae; 10, Papavaraceae; 11, Cruciferae; 12, Capparideae; 13, Resedaceae; 14, Cistineae; 15, Violarieae; 16, Canellaceae; 17, Bixineae

Cohort 3. Polygalineae (Calyx and corolla 5, ovary 2 locular)

Orders: 18, Pittosporaceae; 19, Tremendreae; 20, Polygaleae; 20a, Vochysiaceae

Cohort 4. Caryophyllinae (Free central placentation,ovary 1-locular)

Orders: 21, Frankeniaceae; 22, Caryophyllae; 23, Portulaceae; 24, Tamarascineae

Cohort 5. Guttiferal;es (Stamens numerous, calyx imbricate)

Orders: 25, Elatineae; 26, Hypericineae; 27, Guttiferar; 28, Ternstroemiaceae; 29, Dipterocarpeae; 30, Chlaenaceae

Cohort 6. Malveles (Stamens numerous, calyx valvate)

Orders: 31, Malvaceae, 32, Sterculiaceae;, 33 Tiliaceae

Series II. **DISCIFLORAE** (Ovary superior, immersed in the disc of flower)

Cohort 7. Geraniales (Ovules pendulous, raphe ventral)

Orders: 34, Lineae; 35, Humiriaceae; 36, Malpighiaceae; 37, Zygophylleae; 38, Geraniaceae; 39, Rutaceae; 40, Simarubeae; 41, Ochnaceae; 42, Burseraceae; 43, Meliaceae; 44, Chailletiaceae

Cohort 8. Olacales (Ovules pendulous, raphe dorsal)

Orders: 45, Olacineae; 46, ilicineae; 46a, Cyrilleae

Cohort 9. Celastrales (Ovules erect, raphe ventral)

Orders: 47, Celastrineae; 48, Stackhousieae; 49, Rhamneae; 50, Ampelideae

Cohort 10. Sapidales (Ovules scending, raphe ventral or inverted)

Orders: 51, Sapidaceae; 52, Sabiaceae; 53, Anacardiaceae

Ordines anomaly: 54, Coriareae; 55, Moringeae

Series III. **CALYCIFLORAE** (Sepals united, often adnate to ovary; stamens peri- or, epigynous, ovary often inferior)

Cohort 11. Rosales (Flowers usually bisexual, regular or irregular; stamens indefinite, often twice or more the number of petals, styles distinct)

Orders: 56, Connaraceae; 57, Leguminosae;, 58, Rosaceae; 59, Saxifragaceae; 60, Crassulaceae; 61, Droseraceae; 62, Hamamelideae; 63, Bruniaceae; 64, Halorageae

Cohort 12. Myrtales(Flowers regular or irregular, stamens definite, rarely indefinite,

floewers peri-or epigynous

Orders: 65, Rhizophoreae; 66, Cobretaceae; 67, Myrtaceae; 68, Melastomaceae; 69, Lythrarieae; 70, Onagraceae

Cohort 13. Passiflorales (Ovary syncarpous, parietal placentation)

Orders: 71, Samydaceae; 72, Loaseae; 72, Turneraceae; 74, Passifloreae; 75, Cucurbitaceae; 76, Begoniaceae; 77, Datisceae

Cohort 14. Ficoidales (Flowers regular or irregular, ovary syncarpous, inferior to Superior, parietal, basal or axile placentation)

Orders: 78, Cacteae; 79, Ficoideae

Cohort 15. Umbellales (Flowers regular, usually bisexual, ovary inferior, umbel inflorescence)

Orders: 80, Umbellifereae; 81, Araliaceae; 82, Cornaceae

Sub Class 2. GAMOPETALAE (Petals fused)

Series IV. Inferae (Ovary inferior, stamens no. = petal no. and alternating with them)

Cohort 16. Rubiales (Stamens epipetalous, anthers distinct, ovary 2- many locular,ovules 1- many)

Orders: 83, Caprifoliaceae; 84, Rubiaceae

Cohort 17. Asterales (Stamens epipetalous, ovary 1- locular, 1-ovuled)

Orders: 85, Valerianeae; 86, Dipsaceae; 87, Calycereae; 88, Compositae;

Cohort 18. Campanales (Stamens free, ovary 2-6 locular, ovules many)

Orders: 89, Stylideae; 90, Goodenovieae; 91, Campanulaceae

Series V. Heteromerae (Ovary superior, stamen as many or double the number ofpetals, carpels more than 2)

Cohort 19. Ericales (stamens double or as many as corolla lobes and alternating with them, ovary 2-many locular)

Orders: 92, Vacciniaceae; 93, Ericaceae; 94, Monotropeae; 95, Epacrideae; 96, Diapensiaceae; 97, Lennoaceae

Cohort 20. Primulales (Stamens as many as petals and opposite them, ovary 1locular)

Orders: 98, Plumbagineae; 99, Primulaceae;, 100, Myrsineae

Cohort 21. Ebenales(Stamens as many as petals and opposite them, ovary 2-many locular)

Orders: 101, Sapotaceae; 102, Ebenaceae; 103, Styraceae

Series VI. Bicarpellatae (Stamens as many as petals and alternating with them, ovary bicarpellay and superior)

Cohort 22. Gentianales (Corolla regular, leaves opposite)

Orders: 104, Oleaceae; 105, Salvadoraceae; 106, Apocynaceae; 107, Asclepiadaceae; 108, Loganiaceae; 109, Gentianaceae

Cohort 23. Polemoniales (Corolla actinomorphic, leaves alternate)

Orders: 110, Polemoniaceae; 111, Hydrophyllaceae; 112, Boraginaceae; 113, Convolvulaceae; 114, Solanaceae

Cohort 24. Personales (Corolla zygomorphic, ovules many)

Orders: 115, Scrophulariaceae; 116, Orobanchaceae; 117, Lentibulariaceae; 118, Columelliaceae; 119, Gesneriaceae; 120, Bignoniaceae; 121, Pedaliaceae; 122, Acanthaceae

Cohort 25. Lamiales (Corolla zygomorphic, ovules 4)

Orders: 123, Myoporineae; 124, Selagineae; 125, Verbenaceae; 126, Labiatae

Ordo anomalus: 127, Plantagineae

Sub Class 3. MONOCHLAMYDEAE (Perianth 1 two seriate, mostly sepaloid)

Series VII. Curvembryeae (Endosperm mealy, embryo curved, ovary one ovuled)

Orders: 128, Nyctagineae; 129, Illecebraceae; 130, Amaranthaceae; 131,Chenopodiaceae; 132, Phytolaccaceae; 133, Batideae; 134, Polygonaceae

Series VIII. Multiovulatae aquaticae (Many ovuled aquatic herbs)

Order: 135, Podostemaceae

Series IX. Multiovulatae terrestris (Many ovuled terrestrial herbs)

Orders: 136, Nepanthaceae; 137, Cytineae; 138, Aristolochiaceae

Series X. Micrembryeae (Carpel 1-2 ovuled, seed endospermic, ebryo minute)

Orders: 139, Piperaceae; 140, Chloranthaceae; 141, Myristiceae; 142, Monimiaceae

Series XI. Daphnales (Ovary usually monocarpellary, ovules 1-few, stamens perigynous, perianth usually sepaloid)

Orders: 143, Laurineae; 144, Proteaceae; 145, Thymeliaceae; 146, Penaeceae; 147, Elaeagnaceae

Series XII. Achlamydosporeae (Ovary 1 locular, 1-3 ovuled, seeds without testa)

Orders: 148, Loranthaceae; 149, Santalaceae; 150,Balanophoreae

Series XIII. Unisexuales (Flowers unisexual)

Orders: 151, Euphorbiaceae; 152, Balanopseae; 153, Urticaceae; 154, Platanaceae; 155, Leitnerieae; 156, Juglandeae; 157, Myricaceae; 158, Casuarinaceae; 159, Cupuliferae

Series XIV. **Anomalous families** (Ordines anomaly)

Orders: 160, Salicineae; 161, Lacistemaceae; 162, Empeteraceae; 165, Ceratophylleae

CLASS 2 – GYMNOSPERMAE

Orders: 164, Gnetales; 165, Coniferae; 166, Cycadaceae

CLASS 3- **MONOCOTYLEDONES** (One cotyledon, endogenous growth)

Series XV. **Microspermae** (Inner perianth petaloid, ovary inferior, seeds minute)

Orders: 167, Hydrocharideae; 168, Murmanniaceae; 169, Orchidaceae;

Series XVI. **Epigynae** (Inner perianth petaloid, ovary inferior, endosperm plenty)

Orders: 170, Scitamineae; 171, Bromeliaceae; 172, Haemodoraceae; 173, Irideae; 174, Amaryllideae; 175, Taccaceae; 176, Dioscoreaceae

Series XVII. **Coronarieae** (Inner perianth petaloid, ovary free and superior)

Orders: 177, Roxburghiaceae; 178, Liliaceae; 179, Pontederiaceae; 180, Philydraceae; 181, Xyridaceae; 182, Mayaceae; 183, Commelinaceae; 184, Rapateaceae

Series XVIII. **Calycinae**(Inner perianth sepaloid, ovary free)

Orders: 185, Flagellariaceae; 186, Juncaceae; 187, Palmae

Series XIX. **Nudiflorae**(Perianth absent or represented by hairs or scales)

Orders: 188, Pandaneae; 189, Cyclanthaceae; 190, Typhaceae; 191, Aroideae; 194, Lemnaceae

Series XX. Apocarpae (Perianth in 1 or 2 whorls, or absent; ovary superior, apocarpous, no endosperm)

Orders: 193, Triurideae; 194, Alismaceae; 195, Niadaceae

Series XXI. **Glumaceae** (Flowers solitary, sessil in the axils of bracts and arranged in heads or spikelets with bracts; perianth of scales or none, ovary1- locular, 1- ovuled)

Orders: 196, Eriocauleae; 197, Centrolepideae; 198, Restiaceae; 199, Cyperaceae; 200, Gramineae

Phylogenetic Classifications

Evolutionary theory proposed by Darwin (1859) influenced taxonomy in various ways. This theory states that all species today are the result of an extensive process of evolution that began several billion years ago with single celled organisms. As the theory of evolution became widely accepted, it

displaced other explanation for the origin and diversity of life, such as spontaneous or abiogenesis (hypothetical generation of life from non-living matter) of complex organisms and creationism (belief that the origin of universe and everything on it is due to an event of creation brought about by the deliberate act of God). Plants and animals were now recognized as being dynamic entities that change through time, and one species-giving rise to successive species.

Once the existence of the evolutionary process was acknowledged, the natural systems of de Candolle and also of Bentham and Hooker were found to be inadequate and classifications based on phylogeny (presumed ancestral history) were proposed. Phylogenetic systems, have of course, their base in natural systems, and like these are built upon understanding of plant morphology with an addition of evolutionary concept. Since Darwin's time most botanists have tried to incorporate evolutionary relationships into classifications.

A.W. Eichler (1839-1887), a German botanist divided plants into Phanerogamae and Cryptogamae. Phanerogamae (seed plants) were divided into Gymnospermae and Angiospermae, and the latter were further divided into Monocotyleae and Dicotyleae. He arranged families from primitive to advance series.

Adolf Engler (1844-1930) and **Karl Prantle** (1849-1893). These two German botanists published jointly a multivolume work *Die Naturlichen Pflangen Familien* (1887-1915) wherein they proposed their system of classification. In this system the flowering plants were supposed to have originated along two independent lines from unknown, wind pollinated gymnosperms. One line led to the most primitive modern dicots, the "Amentiferae", a group of wind-pollinated plants with small, apetalous flower in unisexual inflorescence. The other line led to the most primitive modern monocots, the Pandanales.Thus, they proposed a polyphylatic origin of angiosperms. The evolutionary trends as suggested by Engler and Prantl are as under:

Apetalous →free petals→ connate
Actinomorphic →zygomorphic
Unisexual →bisexual
Hypogynous→epigynous

Their work included the keys and description of all known genera of plants, from algae to angiosperms. They divided the plant kingdom into 14 divisions. Divisions 1-13 deal with algae, fungi, bryophytes and pteridophytes; division 14 pertains to the classification of embryophyta or seed plants. Embryophyta is divided into two sub-divisions – the Gymnospermae and Angiospermae. Classification of Engler and Prantl is followed in many American and Continental European herbaria for the arrangement of plant specimens.

Outline of Engler and Prantl's system

Division: Embryophyta (seed plants)
Subdivisions

Gymnospermae
Angiospermae (Ovules enclosed in the ovary and vessels present)

Class

Monocotyledonae (11orders and 45 families)

Dicotyledoneae

Sub-class

Archichlamydeae (Apetalae) Perianth single or double whorled or absent, corolla usually polypetalous. (37 orders and 227 families)

Metachlamydeae (Sympetalae) Perianth in two whorls. Corolla usually gamopetalous; stamens twice or as many as petals, epipetalous. (11 orders and 64 families)

Charles E Bessey (1845-1919), was the first American to make significant contribution to plant classification. He devised a set of about 30 'dicta' or guiding principles stating which features was primitive and which were advanced in angiosperms. Bessey considered Ranales as the basal group from which both monocoyledons and dicotyledons have evolved, but also believed that all angiosperms originated from strobiliferous, cycad ancesters.

John Hutchinson (1884-1972), a British botanist associated with Royal Botanic Gardens, Kew proposed a system which first appeared in Kew Bulletins and later in a two volume work The families of Flowering Plants (1926, 1934). This work went under several revisions and final edition appeared in 1973. His classification was based on 24 principles that are similar to Bessey's dicta. He recognized 418 families of flowering plants belonging to 112 orders.

Angiosperms were considered monophylatic in origin from some hypothetical proangiosperms. Dicots are considered more primitive than monocots, and were regarded as evolved along two separate lines, Herbaceae – including predominantly herbaceous families - and Lignosae – including fundamentally woody families. The Magnoliales are considered most primitive of Lignosae and Ranales the most primitive of Herbaceae. The main drawback of the system is the primary division into woody and herbaceous lines and neglecting other equally important floral characters. This has resulted into wide separation of some families that resemble one another rather closely on the basis of floral characters.

Subsequently many improved systems of classifications based on information from various sources have been proposed. Some of the contemporary botanists who have proposed phylogenetic classifications are:

Armen Takhtajan (1910-1997). Russian. The latest classification of Takhtajan was published in 1980 with the heading "Outline of the classification of flowering plants".

Arthur Cronquist (1919-1992). American. Published his system in his book, *Evolution and Classification of Flowering Plants* (1968).

Robert Thorne (1920). American. Published " A synopsis of a putatively phylogenetic system of classification of flowering plants" in 1968.

Rolf Dahlgren (1932-1987). Danish. He initially published his system in a textbook of angiosperm taxonomy in 1974, which was revised subsequently in 1975 and 1980.