A TEXT BOOK OF CONSERVATION ECOLOGY AND PHYTOGEOGRAPHY

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PREFACE

Exponential growth in many areas of basic fundamentals made it necessary in some cases to write several chapters on the same topic which was covered in a single chapter in the earlier book. Similarly, in the present volume, separate new chapters have been written on topics which in the earlier title either did not figure at all or were each covered very briefly as a part of a chapter. In the present book, for instance in separate chapters have been written on new topics. The students of Biology at the post graduate (P.G.) under graduate (U.G.) levels needed to the recent Global changes and developments. The book is written in simple language so that the students can easily grasp the matter. Some important terms has been incorporated. So that the students may search the useful related for competitive examinations. In the recent years included in the syllabus of almost all Indian Universities in various subjects of Biology or Life Sciences as an independent evergreen subject.

In presenting this volume, I like to express gratitude to my readers for the love, affection and appreciation, expressed either through letters or in personal meetings. Three decades of book writing activity has been full of pleasure and excitement for me, and gave me an opportunity to learn for writing. I would have never understood many of the concepts if I did not have the self imposed pressure of the readership, because I thought I should understand what I write of the journals, and the internet facility both in the office and at my residence facilitated greatly the book writing activity. The research work carried out in the laboratory and published in important international journals during this period brought me recognition and encouraged me to write several chapters in the present book. Several of my students in the laboratory helped me either in writing some of the chapters or in preparing the list of references and appendix given at the end of this volume. Excellent technical help by rearranging the text and incorporating corrections in the text and figures, as and when it was necessary. I am also thankful to the publishers. I hope that the book will serve the purpose for which it is written, and that the teachers and student will find it useful for various courses in Biological Science prescribed for B. Sc and M. Sc degrees in life sciences and biotechnology. The teachers may also use this book for farming new syllabi and for revising the old ones. However, despite several rounds of reading, the book may still have some printing errors. There may also be errors and omissions of technical nature, since in a vast and fast expanding subject like Botany Biotechnology; one cannot claim to have known everything, despite his best efforts. I will appreciate, if these errors or omissions are brought to my notice, so that the future reprints and editions may become free of these errors or omissions and may prove more useful to the readers.

I am thankful to Department Head, BOS, Staff and Research Scholars (Botany) my family members, inspiration and cooperation my wife and children's Teachers, Friends, Students and Well-Wishers. I hope that this book will be useful to students in Life Sciences.

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CHAPTER- I

PRINCIPLES AND RATIONALE

Conservation biology, or popularly known as conservation ecology, is the science of analyzing and protecting Earth's biological diversity. Conservation biology draws from the biological, physical and social sciences, economics, and the practice of natural-resource management. Conservation ecology addresses population dynamics issues associated with the small population sizes of rare species (e.g. minimum viable-populations). The term "conservation biology" refers to the application of science to the conservation of genes, populations, species, and ecosystems. Conservation biology is the scientific study of the phenomena that affect the maintenance, loss, and restoration of biological diversity.

In the 19th century actions in the United Kingdom, the USA and certain other western countries emphasized the protection of habitat areas pursuant to visions of such people as John Muir and Theodore Roosevelt. It was not until the mid 20th century did efforts arise to target individual species for conservation, notably efforts in big cat conservation in South America led by the New York Zoological Society. By the 1970s, led primarily by work in the USA under the Endangered Species Act along with Biodiversity Action Plans developed in Australia, Sweden, the United Kingdom, hundreds of specific species protection plans ensued. The society for Conservation Biology is a global community of conservation professionals dedicated to advancing the science and practice of conserving Earth's biological diversity.

Presently the Earth is undergoing the Holocene Mass Extinction, an era of unprecedented number of species extinctions. Human influence over the Earth's ecosystems has been so extensive within the last 10,000 years, that scientists have difficulty estimating the total number of species lost in this era; that is to say the rates of deforestation, reef destruction, wetlands filling and other human acts are proceeding much faster than human assessment of the Earth's species. The matter of ongoing species loss is made more complex by the fact that most of the Earth's species have not been described or evaluated for endangerment. The IUCN has found that 23 percent of vertebrates, 53 percent of invertebrates and 70 percent of plants that have been evaluated are designated as endangered or threatened. (The IUCN does not disaggregate endangered from critically endangered or threatened for the purpose of these statistics.)

Historically the main threat to biodiversity has been a set of threats generated from the overpopulation of humans: mass agriculture, deforestation, overgrazing, slash-and-burn, urban development, pesticide use. Worldwide, the effects of global warming add a potentially catastrophic threat to global biological diversity; a 2004 study by Chris Thomas, Lee Hannah and et al. estimated that 15 to 37 percent of all species would become extinct by 2050.

Importance of Biological Diversity

Biologist Bruce Walsh of, the University of Arizona state's three reasons for scientific interest in the preservation of species; genetic or medical resources, ecosystem stability, and ethics and today the scientific community "stress [es] the importance" of maintaining biodiversity. Biodiversity provides many ecosystem services that are often not readily visible. It plays an essential part in regulating the chemistry of our atmosphere, pollinating crops and generating water supply. Biodiversity is directly involved in recycling nutrients and providing fertile soils. Experiments with controlled environments have shown that humans cannot easily build ecosystems to support human needs; for example insect pollination cannot be mimicked by man-made construction.

The total value of ecosystem services may amount to trillions of dollars in ecosystem services per annum to mankind. For example, one segment of North American forests has been assigned an annual value of 250 billion dollars; as another example, honey-bee pollination, a small segment of ecosystem services, is estimated to provide between 10 and 18 billion dollars of value per annum. The value of ecosystem services on one New Zealand Island has been imputed to be as great as the GDP of that region.

Conservation biologists trace the ethics that guide their work back to early spiritual philosophies, including the Tao, Shinto Hindu, Islamic and Buddhist traditions. In the west origins of concern for the destruction of the natural environment by man can be traced to Plato; however, modern roots of conservation biology can be found in the-late 18th century Enlightenment period particularly in England and Scotland. A number of thinkers, among them notably Lord Monboddo, described the importance of "preserving nature"; much of this early emphasis had its origins in Christian theology. By the early 1800s biogeography was ignited through efforts of Von Humboldt, DeCandolle, Lyell and Darwin; their efforts, while important in relating species to their environments, fell short of actual conservation.

The term conservation came into use in the late 19th century and referred to the management, mainly for economic reasons, of such natural resources as timber, fish, game, topsail, pastureland, and minerals, and also to the preservation afforests wildlife, parkland, wilderness, and watersheds. Western Europe was the source of much 19th century progress for conservation biology, particularly the British Empire; however, - the United States began making sizable contributions to this field starting with thinking of Thoreau and taking form in congress passing the Forest Act of 1891, John Muir's work and the founding of the Sierra Club in 1895, founding of the New York Zoological - Society in 1895 and establishment of a series of national forests and preserves by Theodore Roosevelt front 1901 to 1909.

In the early 20th century the New York Zoological Society was instrumental in developing concepts of establishing preserves for particular species and conducting the necessary conservation studies to determine the suitability of specific locations that are most appropriate as conservation priorities; the work of Henry Fairfield Osborn Jr., Archie Carr and Archie Carr III is notable in this era. By the early 1970s national and international governmental agencies became more active in the conservation of biodiversity. Notably the United Nations acted to conserve sites of outstanding cultural or natural import rice to the common heritage of mankind.

The program was adopted by the General Conference of UNESCO in 1972. As of 2006, a total of 830 sites are listed: 644 cultural, 162 natural. The first country to pursue aggressive biological conservation through national legislation was the USA, which passed back to back legislation in the Endangered Species Act (1966) and National Environmental Policy Act (1970), which together injected major funding and protection measures to large scale habitat protection and threatened species research. By 1992 most of the countries of the world had become committed to the principles of conservation of biological diversity with the Convention on Biological Diversity; subsequently many countries began programs of Biodiversity Action Plans to identify and conserve threatened species within their borders, as well as protect associated habitats. The science of ecology has clarified the workings of the biosphere; i.e., the complex interrelationships among humans, other species, and the physical environment; moreover, the burgeoning human population, and associated agriculture, industry and its ensuing pollution have demonstrated how easily ecological relationships can be disrupted.

Biodiversity

Biodiversity is the variation of taxonomic life forms within a given ecosystem, biome or for the entire Earth. Biodiversity is often a measure of the health of biological systems.

Evolution and Meaning of the Term

Biodiversity is a neologism and a portmanteau word, from biology arid diversity. The Science Division of The Nature Conservancy used the term "natural diversity" in a 1975 study, "The Preservation of Natural Diversity." The term biological diversity was used even before that by conservation scientists like Robert E. Jenkins and Thomas Lovejoy. The word biodiversity itself may have been coined by W.G. Rosen in 1985 while planning the National Forum on Biological Diversity organized by the" National Research Council (NRC) which was to be held in 1986, and first appeared in a publication in 1988 when entomologist E.O. Wilson used it as the title of the proceedings of that forum. The word biodiversity was deemed more effective in terms of communication than biological diversity.

Since 1986 the terms and the concept have achieved widespread use among biologists, environmentalists, political leaders, and concerned citizens worldwide. It is generally used to equate to a concern for the natural environment and nature conservation. This use has coincided with the expansion of concern over extinction observed in the last decades of the 20th century. The term "natural heritage" pre-dates "biodiversity", though it is a less scientific term and more easily comprehended in some ways by the wider audience interested in conservation. "Natural Heritage" was used when Jimmy Carter set up the Georgia Heritage Trust while he was governor of Georgia; Carter's trust dealt with both natural and cultural heritage. It would appear that Carter picked the term up from Lyndon Johnson, who used it in a 1966 Message to Congress. "Natural Heritage" was picked up by the Science Division of The Nature

Conservancy when, under Jenkins, it launched in 1974 the network of State Natural Heritage Programs. When this network was extended outside the USA, the term "Conservation Data Center" was suggested by Guillermo Mann and came to be preferred.

The most straightforward definition is "variation of life at all levels of biological organization". A second definition holds that biodiversity is a measure of the relative diversity among organisms present in different ecosystems. "Diversity" in this definition includes diversity within a species and among species, and comparative diversity among ecosystems. A third definition that is often used by ecologists is the "totality of genes, species, and ecosystems of a region". An advantage of this definition is that it seems to describe most circumstances and present a unified view of the traditional three levels at which biodiversity has been identified.

1. Genetic diversity - diversity of genes within a species. There is a genetic variability among the populations and the individuals of the same species. (See also population genetics.)
2. Species diversity - diversity among species in an ecosystem. "Biodiversity hotspots" are excellent examples of species diversity.
3. Ecosystem diversity - diversity at a higher level of organization, the ecosystem. To do with the variety of ecosystems on Earth.

This third definition, which .conforms to the traditional five organization layers in biology, provides additional justification for multilevel approaches. The 1992 United Nations Earth Summit in Rio de Janeiro defined "biodiversity" as "the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems". This is, in fact, the closest thing to a single legally accepted definition of biodiversity, since it is the definition adopted by the United; Nations Convention on Biological Diversity. If the gene is the fundamental unit of natural selection, according to E.O. Wilson, the real biodiversity is genetic diversity. For geneticists, *biodiversity* is the diversity of genes and organisms. They study processes such as mutations, gene exchanges, and genome dynamics that occur at the DNA level and generate evolution.

For biologists, biodiversity is the gamut of organisms and species and their interactions. Organisms appear and become extinct; sites are colonized and some species develop social organizations to improve their varied strategies of reproduction. For ecologists, biodiversity is also the diversity of durable interactions among species. It not only applies to species; but also to their immediate environment (biotope) and their larger ecoregion. In each ecosystem, living organisms are part of a whole, interacting with not only other organisms, but also with the air, water, and soil that surround them. Large variety of plants and animals which form a complex web of ecosystem. Diversity exists in their form and functions. Multiple networks bind each species together.

Biodiversity is a broad concept, so a variety of objective measures have been created in order to empirically measure of biodiversity. Each measure of biodiversity relates to a particular use of the data. For practical conservationists, this measure should quantify a value that is broadly shared among locally affected people. For others, a more economically defensible definition should allow the ensuring of continued possibilities for both adaptation and future use by people, assuring environmental sustainability.

As a consequence, biologists argue that this measure is likely to be associated with the variety of genes. Since it cannot always be said which genes are more likely to prove beneficial, the best choice for conservation is to assure the persistence of as many genes as possible? For ecologists, this latter approach sometimes considered too restrictive, as it prohibits ecological succession. Biodiversity is usually plotted as taxonomic richness of a geographic area, with some reference to a temporal scale. Whittaker described three common metrics used to measure species-level biodiversity, encompassing attention to species richness or species evenness.

- Species richness - the most primitive of the indices available.
- Simpson index
- Shannon index

There are three other indices which are used by ecologists

- Alpha diversity refers to diversity within a particular area, community or ecosystem, and is measured by counting the number of taxa within the ecosystem

(usually species)

- Beta diversity is species diversity between ecosystems; this involves comparing; the number of taxa that are unique to each of the ecosystems.
- Gamma diversity is a measure of the overall diversity for different ecosystems within a region.

Biodiversity Distribution

Biodiversity is not distributed evenly on Earth. It is consistently richer in the tropics and in other localized regions such as the California Floristic Province. As one approaches Polar Regions one generally finds fewer species. Flora and fauna diversity depends on climate, altitude, soils and the presence of other species. In the year 2006 large numbers of the Earth's species are formally classified as rare or endangered or threatened species; moreover, most scientists estimate that there are millions more species actually endangered which have not yet been formally recognized. About 40 percent of the 40,177 species assessed using the IUCN Red List criteria, are now listed as threatened species with extinction a total of 16,119 species.

A biodiversity hotspot is a region with a high level of endemic species. These biodiversity hotspots were first identified by Dr. Norman Myers in two articles in the scientific journal The Environmentalist. Hotspots unfortunately tend to occur near areas of dense human habitation, leading to threats to their many endemic species. As a result of the pressures of the rapidly growing human population, human activity in many of these areas is increasing dramatically. Most of these hotspots are located in the tropics, and most of them are forests.

For example, Brazil's Atlantic Forest contains roughly 20,000 plant species, 1350 vertebrates, and millions of insects, about half of which occur nowhere else in the world. The island of Madagascar including the unique Madagascar dry deciduous forests and lowland rainforests possess a very high ratio of species endemism and biodiversity, since the island separated from mainland Africa 65 million years ago, most of the species and ecosystems have evolved independently producing unique species different than other parts of Africa.

Many regions of high biodiversity (as well as high endemism) arise from very specialized habitats which require unusual adaptation mechanisms. For example the peat bogs of Northern Europe and the alvar regions such as the Stora Alvaret on Oland, Sweden host a large diversity of plants and animals, many of which are not found elsewhere. Biodiversity found on Earth today is the result of 4 billion years of evolution. The origin of life is not well known to science, though limited evidence suggests that life may already have been well-established only a few 100 million years after the formation of the Earth. Until approximately 600 million years ago, all life consisted of bacteria and similar single-celled organisms.

The history of biodiversity during the Phanerozoic (the last 540 million years), starts with rapid growth during the Cambrian explosion-a period during which nearly every phylum of multicellular organisms first appeared. Over the next 400 million years or so, global diversity showed little overall trend, but was marked by periodic, massive losses of diversity classified as mass extinction events. The apparent biodiversity shown in the fossil record suggests that the last few million years include the period of greatest biodiversity in the Earth's history. However> not all scientists support this view, since there is considerable uncertainty as to how strongly the fossil record is biased by the greater availability and preservation of recent geologic sections. Some (e.g. Alroy et al. 2001) argue that corrected for sampling artifacts, modern biodiversity is not much different from biodiversity 300 million years ago. Estimates of the present global macroscopic species diversity vary from 2 million to 100 million species, with a best estimate of somewhere near 10 million

Most biologists agree however that the period since the emergence of humans is part of a new mass extinction, the Holocene extinction event, caused primarily by the impact humans are having on the environment. At present, the number of species estimated to have gone extinct as a result of human action is still far smaller than are observed during the major mass extinctions of the geological past. However, it has been argued that the present rate of extinction is sufficient to create a major mass extinction in less than 100 years. Others dispute this and suggest that the present rate of extinctions could be sustained for many thousands of years before the loss of biodiversity matches the more than 20% losses seen in past global extinction events.

New species are regularly discovered (on average about three new species of birds each year) and many, though discovered, are not yet classified (an estimate states that about 40% of freshwater fish from South America are not yet classified). Most of the terrestrial diversity is found in tropical forests.

Benefits of Biodiversity

There are a multitude of benefits of biodiversity in the sense of one diverse group aiding another such as

Resistance to Catastrophe: Monoculture, the lack of was a contributing factor to several agricultural disasters in history, including the Irish Potato Famine, the European wine industry collapse in the late 1800s, and the US Southern Corn Leaf Blight epidemic of 1970.

Food and Drink: Biodiversity provides food for humans. About $0 percent of our food supply comes from just 20 kinds of plants. Although many kinds of animals are utilized as food, again most consumption is focused on a few species. There is vast untapped potential for increasing the range of food products suitable for human consumption, provided that the high present extinction rate can be halted.

Medicines: A significant proportion of drugs are derived, directly or indirectly, from biological sources; in most cases these medicines cannot presently be synthesized in a laboratory setting. Moreover, only a small proportion of the total diversity of plants has been thoroughly investigated for potential sources of new drugs. Many medicines and antibiotics are also derived from microorganisms.

Industrial Materials: A wide range of industrial materials are derived directly from biological resources. These include building materials, fibers, dyes, resins, gums, adhesives, rubber and oil. There is enormous potential for further research into sustainably utilizing materials, from a wider diversity of organisms.

Other Ecological Services: Biodiversity provides many ecosystem services that are often not readily visible. It plays a part in regulating the chemistry of our atmosphere and water supply. Biodiversity is directly involved in recycling nutrients and providing fertile soils. Experiments with controlled environments have shown that humans cannot easily build ecosystems to support human needs; for example insect pollination cannot be mimicked by man-made construction, and that activity alone represents tens of billions of dollars in ecosystem services per annum to mankind.

Leisure, Cultural and Aesthetic Value: Many people derive value from biodiversity through leisure activities such as enjoying a walk in the countryside, bird watching or natural history programs on television. Biodiversity has inspired musicians, painters, sculptors, writers and other artists. Many cultural groups view themselves as an integral part of the natural world and show respect for other living organisms.

Threats to Biodiversity

During the last century, erosion of biodiversity has been increasingly observed. Some studies show that about one of eight known plant species is threatened with extinction. Some estimates put the loss at up to 140,000 species per year (based on Species-area theory) and subject to discussion. This figure indicates unsustainable ecological practices, because only a small number of species come into being each year. Almost all scientists acknowledge that the rate of species loss is greater now than at any time in human history, with extinctions occurring at rates hundreds of times higher than background extinction rates.

Destruction of Habitats: Most of the species extinctions from 1000 AD to 2000 AD are due to human activities, in particular destruction of plant and animal habitats. Elevated rates of extinction are being driven by human consumption of organic resources, especially related to tropical forest destruction. While most of the species that are becoming extinct are not food species, their biomass is converted into human food when their habitat is transformed into pasture, cropland, and orchards. It is estimated that more than 40% of the Earth's biomass is tied .up in only the few species that represent humans, livestock and crops. Because an ecosystem decreases in stability as its species are made extinct, these studies warn that the global ecosystem is destined for collapse if it is further reduced in complexity.

Factors contributing to loss of biodiversity are: overpopulation, deforestation, pollution (air pollution, water pollution, soil contamination) and global warming or climate change, driven by human activity. These factors while all stemming from over population; produce a cumulative impact upon biodiversity. Some characterize loss of biodiversity not as ecosystem degradation but by conversion to trivial standardized ecosystems (e.g., monoculture following deforestation). In some countries lack of property rights or access regulation to biotic resources necessarily leads to biodiversity loss (degradation costs having to be supported by the community).

Exotic Species: The rich diversity of unique species, across many parts of the world exist only because they are separated by barriers, particularly large rivers; seas, oceans, mountains and deserts from other species of other land masses, particularly the highly fecund, ultra-competitive, generalist "super-species". These are barriers that could never be crossed by natural processes, except for many millions of year's in the future through continental drift. However humans have invented ships and airplanes, and now have the power to bring into contact species that never have met in their evolutionary history, and on a time scale of days, unlike the centuries that historically have accompanied major animal migrations.

The widespread introduction of exotic species by humans is a potent threat to biodiversity. When exotic species are introduced to ecosystems and establish self-sustaining populations, the endemic species in that ecosystem that have not evolved to cope with the exotic species, may not survive The exotic organisms may be either predators, parasites, or simply aggressive species that deprive indigenous species of nutrients, water and light. These exotic or invasive species often have features due to their evolutionary background and environment that makes them competitive, and similarly makes endemic species defenseless and/or uncompetitive against these exotic species. As a consequence of the above, if humans continue to combine species from different ecoregion, there is the potential that the world's ecosystems will end up dominated by relatively a few, aggressive, cosmopolitan "super-species"? Declines in amphibian populations have been observed since 1980s. These might critically threaten global biodiversity.

The conservation of biological diversity has become a global concern. Although not everybody agrees on extent and significance of current extinction, most consider biodiversity essential. There are basically two main types of conservation options, in-situ conservation and ex-situ conservation. In-situ is usually seen as the ideal conservation strategy. However, its implementation is sometimes infeasible. For example, destruction of rare or endangered species' habitats sometimes requires ex-situ conservation efforts. Furthermore, ex-situ conservation can provide a backup solution to in-situ conservation projects. Some believe both types of conservation i are required to ensure proper preservation. An example of an in-situ conservation effort is the setting-up of protection areas. Examples of ex-situ conservation efforts, by contrast, would be planting germplasts in seed banks, or growing the Wollemi Pine in nurseries. Such efforts allow the preservation of large populations of plants with minimal genetic erosion. At national levels a Biodiversity Action Plan is sometimes prepared to state the protocols necessary to protect an individual species. Usually this plan also details extant data on the species and its habitat. In the USA such a plan is called a Recovery Plan.

The threat to biological diversity was among the hot - topics discussed at the UN World Summit for Sustainable Development, in hope of seeing the foundation of a Global Conservation Trust to help maintain plant collections.

Judicial Status of Biological Diversity

Biodiversity is beginning to be evaluated and its evolution analyzed (through observations, inventories, conservation) as well as being taken into account in political and judicial decisions.

- The relationship between law and ecosystems is very ancient and has consequences for biodiversity. It is related to property rights, both private and public. It can define protection for threatened ecosystems, but also some rights and duties (for example, fishing rights, hunting rights).
- Law regarding species is a more recent issue. It defines species that must be protected because they may be threatened by extinction. Some people question application of these laws. The U.S. Endangered Species Act is an example of an attempt to address the "law and species" issue.
- Laws regarding gene pools are only about a century old. While the genetic approach is not new (domestication, plant traditional selection methods), progress made in the genetic field in the past 20 years have led to a tightening of laws in this field. With the new technologies of genetic analysis and genetic engineering, people are going through gene patenting, processes patenting, and a totally new concept of genetic resources. A very hot debate today seeks to define whether the resource is the gene, the organism itself, or its DNA.

The 1972 UNESCO convention established that biological resources, such as plants, were the common heritage of mankind. These rules probably inspired the creation of great public banks of genetic resources, located outside the source countries. New global agreements (e.g. Convention on Biological Diversity), now give sovereign national rights over biological resources. The idea of static conservation of biodiversity is disappearing and being replaced by the idea of dynamic conservation, through the notion of resource and innovation. The new agreements commit countries to conserve biodiversity, develop resources for sustainability and share the benefits resulting from their use. Under new rules, it is expected that bioprospecting or collection of natural products has to be allowed by the biodiversity-rich country, in exchange for a share of the benefits.

Sovereignty principles can rely upon what is better known as Access and Benefit Sharing Agreements (ABAs). The Convention on Biodiversity spirit implies a prior informed consent between the source country and the collector, to establish which resource will be used and for what, and to settle on a fair agreement on benefit sharing. Bioprospecting can become a type of biopiracy when those principles are not respected. Uniform approval for use of biodiversity as a legal standard has not been achieved, however. At least one legal commentator has argued that biodiversity should not be used as a legal standard, arguing that the multiple layers of scientific uncertainty inherent in the concept of biodiversity will cause administrative waste and increase litigation without promoting preservation goals.

Criticisms of the Biodiversity Paradigm

Food

The notion that there is Vast untapped potential' for reducing mankind’s dependence on a relatively small number of domesticated plant and animal species should be challenged. Jared Diamond, based on studies of the domestication of plants and animals, argued that the rarity of species suitable for domestication and their occurrence in just a few parts of the world, determined the limited number of locations in which major civilizations could arise. In recent times there have been many studies of minor food sources, but none of these sources have subsequently become major food crops.

The Founder Effect

The field of biodiversity research (inevitably) suffers from natural human egocentric "myopic" cognitive biases. It has often been criticized for being overly defined by the personal interests of the founders (i.e. terrestrial mammals) giving a narrow focus, rather than extending to other areas where it could be useful. This is termed the *founder effect* by Norse and Irish, (1996). France and Rigg reviewed the biodiversity literature in 1998 and found that there was a significant lack of papers studying marine ecosystems, leading them to dub marine biodiversity research the *sleeping hydra.* More work has been carried out for accessible, diverse coastal systems such as coral reefs than "for inaccessible, species-poor deep sea areas, it has been easier to mobilise public opinion and national legislation for the terrestrial realm, which has higher visibility and falls within countries' territorial boundaries.

Marine conservation involves having to pioneer new and international mechanisms of protection as well as solving methodological problems in marine biology relating to marine ecosystem classification and data-gathering on some of the earth's most difficult species to access and monitor.

Size Bias

Biodiversity researcher Sean Nee points out that the vast majority of Earth's biodiversity is microbial, and that contemporary biodiversity physics is firmly fixated on the visible world (Nee uses "visible" as a synonym for macroscopic). For example, microbial life is very much more metabolically and environmentally diverse than multicellular life. Nee has stated: "On the tree of life, based on analyses of small-subunit ribosomal RNA, visible life consists of barely noticeable twigs. This should not be surprising invisible life had at least three billion years to diversify and explore evolutionary space before the 'visibles' arrived". The reply to this however, is that biodiversity conservation has never focused exclusively on visible (in this sense) species. From the very beginning, the classification and conservation of natural communities or ecosystem types has been a central part of the effort. The thought behind this has been that since invisible (in this sense) diversity is, due to lack of taxonomy, impossible to treat in the same manner as visible diversity, the best that can be done is to preserve a diversity of ecosystem types, thereby preserving as well as possible the diversity of invisible orgasms.

Unified Neutral Theory of Biodiversity (UNTB)

The unified neutral theory of biodiversity and biogeography (here "Unified Theory" or "UNTB") is a theory and the title of a monograph by ecologist Stephen Hubbell. The theory aims to explain the diversity and relative abundance of species in ecological communities, although like other neutral theories of ecology, Hubbell's theory assumes that the differences between members of an ecological community of tropically similar species are "neutral," or irrelevant to their success. Despite contradicting the principle of "survival of the fittest", the theory has been applied successfully to many groups of species/including forest tree species, bacterial populations, moths, British birds, and vascular plants.

Neutrality is defined as per capita ecological equivalence among all individuals of every species at a given trophic level in a food web; "per capita equivalence" means that all species are held to behave (i.e. reproduce and die) in the same way as one another; and individuals of a particular species reproduce and die (behave) in the same way. Early neutral theories- include the broken stick hypothesis-of Robert Mac Arthur and the island biogeography theories of MacArthur and E.O. Wilson.

An ecological community is a group of tropically similar, sympatric species that actually or potentially compete in a local area for the same or similar resources (Hubbell 2001). Under the Unified Theory, complex ecological interactions are permitted among individuals of an ecological community (such as competition and cooperation), provided that all individuals obey the same rules. Asymmetric phenomena such as parasitism and predation are ruled out by the terms of reference; but cooperative strategies such as swarming, and negative interaction such as competing for limited food or light are allowed (so long as all individuals behave in the same way).

The Unified Theory makes a large number of falsifiable hypotheses. Differences between predictions of the Unified Theory and observations are of very small magnitude (needs citation). The Unified Theory also makes predictions that have profound implications for the management of biodiversity, especially the management of rare species. Non-neutral theories of biodiversity would include niche construction and dispersal assembly. These theories are non-neutral because they hold that different species behave in different ways from one another. Other examples of non-neutral explanations would be to hold that older organisms are fitter in the Darwinian sense. Under Hubbell's theory, species drift is allowed to occur via speciation, which would occur with a specific probability per birth. The neutrality of the Unified Theory implies that this probability would be independent of the parent's species (common species have a higher birth rate, and thus the UNTB predicts that speciation occurs more frequently for common species than rare species). The theory predicts the existence of a fundamental biodiversity constant, conventionally written that appears to govern species richness on a wide variety of spatial and temporal scales.

The Unified Theory and Saturation

Although not strictly necessary for a neutral theory, many stochastic models of biodiversity assume a fixed, finite community size. There are unavoidable physical constraints on the total number of individuals that can be packed into a given space (although space per se isn't necessarily a resource, it is often a useful surrogate variable for a limiting resource that is distributed over the landscape; examples would include sunlight or hosts, in the case of parasites). If a 'wide' range of species is considered (say, giant sequoia trees and duckweed, two species that have very different saturation densities), then the assumption of constant community size might not be very good, because density would be higher if the smaller species were monodominant. However, because the Unified Theory refers only to communities of trophically similar, competing species, it is unlikely that population density will vary too widely from one place to another. Exceptions to the saturation principle include disturbed ecosystems such as the Serengeti, where saplings are trampled by elephants and Blue wildebeests; or gardens, where certain species are systematically removed.

Species Abundances

When abundance data on natural populations are collected, two observations are almost universal.

- The most common species accounts for a substantial fraction of the individuals sampled;
- A substantial fraction of the species sampled is very rare. Indeed, a substantial fraction of the species sampled is singletons, that is, species which are sufficiently rare for only a single individual to have been sampled.

Such observations typically generate a large number of questions. Why are the rare species rare? Why is the most abundant species so much more abundant than the median species abundance? A non neutral explanation for the rarity of rare species might suggest that rarity is a result of poor adaptation to local conditions. The UNTB implies that such considerations may be neglected from the perspective of population biology (because the explanation cited implies that the rare species behaves differently from the abundant species).

Stochastic modeling of species abundances under the UNTB

UNTB distinguishes between a dispersal-limited local community of size and so called Meta communities from which species can (re)immigrate and which acts as a heat bath to the local community. The distribution of species in the Meta community is given by a dynamic equilibrium of speciation and extinction. Both community dynamics are modeled by appropriate urn processes, where each individual is represented by a ball with a color corresponding to its species. With a certain rate r randomly chosen individuals reproduce, i.e. add another ball of their own color to the urn. Since one basic assumption is saturation, this reproduction has to happen at the cost of another random individual from the urn which is removed. At a different rate single individuals in the Meta community are replaced by mutants of an entirely new species. Hubbell calls this simplified model for speciation a point mutation, using the terminology of the Neutral theory of molecular evolution. The urn scheme for the metacommunity of J_M individuals is the following.

At each time step take one of the two possible actions.

- With probability (1f) draw an individual at random and replace another random individual from the urn with a copy of the first one.
- With probability draw an individual and replace it with an individual of a new species.

Note that the size J_M of the metacommunity does not change. Note also that this is a point process in time. The length of the time steps is distributed exponentially. For simplicity one can, however, assume that each time step is as long as the mean time between two changes which can be derived from the reproduction and mutation rates *r* and *i*. The probability f is given as i = i % (r + i). At each time step take one of the two actions.

1. With probability (1m) draw an individual at random and replace another random individual from the urn with a copy of the first one.
2. With probability *m* replace a random individual with an immigrant drawn from the metacommunity.

The metacommunity is changing on a much larger timescale and is assumed to be fixed during the evolution of the local community. The resulting distribution of species in the local community and expected values depend on four parameters, J, J_M, e and *m* (or I) and are derived in [Etienne, Alonso 2005], including several simplifying limit cases like the one presented in the previous section (there called). The parameter *m* is a dispersal parameter, if m=1 then the local community is just a sample from the metacommunity. For *m*=0 the local community is completely isolated from the metacommunity and all species will go extinct except one. This case has been analyzed by Hubbell himself [Hubbell 2001].

The case $0 < m < 1$ is characterized by a unimodal species distribution in a Preston Diagram and often, fitted by a log-normal distribution. This is understood as an intermediate state between domination of the most common species and a sampling from the rnetacommunity, where singleton species are most abundant. UNTB thus predicts that in dispersal limited communities rare species become even rarer. The log-normal distribution describes the maximum and the abundance of common species very well but underestimates the number of very rare species considerably which becomes only apparent for very large sample sizes [Hubbell 2001].

Ecozone

An ecozone or biogeographic realm is the largest scale biogeographic division of the earth's surface based on the historic and evolutionary distribution patterns of plants and animals. Ecozones represent large areas of the earth's surface where plants and animals developed in relative isolation over long periods of time, and are separated from one another by geographic features, such as oceans, broad deserts, or high mountain ranges, that formed- barriers to plant and animal migration. Ecozones correspond to the floristic kingdoms of botany or zoogeographic regions of mammal zoology.

Ecozones are characterized by the evolutionary history of the plants and animals they contain. As such, they are distinct from biomes, also known as major habitat types, which are divisions of the earth's surface based on life form, or the adaptation of plants and animals to climatic, soil, and other conditions. Biomes are characterized by similar climax vegetation, regardless of the evolutionary lineage of the specific plants and animals. Each ecozone may include a number of i different biomes. A tropical moist broadleaf forest in Central America, for example, may be similar to one in New Guinea in its vegetation type and structure, climate, soils, etc., but these forests are inhabited by plants and animals with very different evolutionary histories.

The patterns of plant and animal distribution in the world's ecozones was shaped by the process of plate tectonics, which has, redistributed the world's land masses over geological history. The term ecozone, as used here, is a fairly recent development, and other terms, including kingdom, realm, and region, are used by other authorities to denote the same meaning, J, Schultz uses the term "ecozone" to refer his classification system of biomes.

Plant Geography

The systems of biogeographical regions started with Augustin de Candolle in 1820. In his study Essai Elementaire de Geographic Botanique he was very interested in documenting the nature and floral composition, also known as bionies. He was the first author to define endemic areas. It was only after the acceptance of Darwin's theory of evolution that Adolf Engler associated the development of different floras to different regions of the world. His studies on biogeographical regions were based on de Candolle's climatic and physiological studies. Engler's four regions included: the temperate and cold regions of the northern hemisphere; the old world tropics, extending from Africa to northern Australia; the new world tropics, including most of Central and South America; and an "Ancient Ocean" realm which included coastal Chile, Tierra del Fuego, the Cape region and south coast of South Africa, most of Australia, Tasmania, the South Island of New Zealand, and the Subantarctic islands of the southernmost Atlantic, Indian and Pacific oceans.

In 1908, Ludwig Diels placed New Zealand in the Palaetropical Realm and subdivided the "Ancient Ocean" Realm into four realms. British botanist Ronald Good devised a system of six floristic kingdoms (Antarctic, Australian, Boreal, Cape, Neotropical, and Palaeotropical). Good's system, which was further developed by Armeri Takhtajan, is widely used by botanists.

Zoogeography

Nineteenth-century zoologists also contributed to the biogeographical schemes. Alfred Russel Wallace introduced biogeographical regions based on mammal distributions; and. these remain in acceptance by the scientific community. Philip Sclater recognized six regions in 1858 based on passerine bird distributions. Mammalian zoogeographers also identified six kingdoms (African, Australian, Nearctic, Neotropical, Oriental, and Palaearctic), although with different boundaries than those of plant geographers. Many zoogeographers combine the Nearctic and Palearctic into a Holarctic zone. These two zones have been connected by the Bering land bridge for long periods in their histories, and thus have very similar mammal and bird fauna.

Biogeographical Realms

In 1975 Miklos Udvardy proposed a system of 203 biogeographical provinces, which were grouped into eight biogeographical realms (Afrotropical, Antarctic, Australian, Indomalayan, Nearctic, Neotropical, Oceanian, and Palaearctic). Udvardy's goal was to create an integrated ecological land classification system that could be used for conservation purposes.

WWF Ecozones

The WWF ecozones are based largely on the biogeographic realms of Pielou (1979) and Udvardy (1975). A team of biologists convened by the World Wildlife Fund (WWF) developed a system of eight biogeographic realms (ecozones) as part of their delineation of the worlds over 800 terrestrial ecoregion.

- Nearctic 22.9 mil. km^2 (including most of North America)
- Palearctic 54.1 mil. km^2 (including the bulk of Eurasia and North Africa)
- Afrotropic 22.1 mil. km^2 (including Sub-Saharan Africa)
- Indomalaya 7.5 mil. km^2 (including the South Asian subcontinent and Southeast Asia)
- Australasia *7.7* mil. km^2 (including Australia, New Guinea, and neighboring islands). The northern boundary of this zone is known as the Wallace line.**]**
- Neotrdpic 19.0 mil. km^2 (including South America and the-Caribbean)
- Oceania 1.0 mil. km^2 (including Polynesia, Fiji and Micronesia)
- Antarctic 0.3 mil. km^2 (including Antarctica).

The WWF scheme is broadly similar to Udvardy's system, the chief difference being the delineation of the Australasian ecozone relative to the Antarctic, Oceanic, and

Indomalayan ecozones. In the WWF system, The Australasia ecozone includes Australia, Tasmania, the islands of Wallacea, New Guinea, the East Melanesian islands, New Caledonia; and New Zealand. Udvardy's Australian realm includes only Australia and Tasmania; he places Wallacea in the Indomalayan Realm, New Guinea, New Caledonia, and East Melanesia in the Oceanian Realm, and New Zealand in the Antarctic Realm.

Bioregions

The WWF scheme further subdivides the ecozones into bioregions, defined as "geographic clusters of ecoregions that may span several habitat types, but have strong biogeographic affinities, particularly at taxonomic levels higher than the species level (genus, family)." The WWF bioregions are as follows:

1. Afrotropic
2. Antarctic
3. Australasia
- Wallacea
- New Guinea and Melanesia
4. Indomalaya
- Indian Subcontinent
- Indochina
- Sunda Shelf and Philippines
5. Nearctic
- Canadian Shield
- Eastern North America
- Northern Mexico
- Western North America
6. Neotropical
- Amazonia
- Caribbean
- Central America
- Central Andes
- Eastern South America
- Northern Andes

- Orinoco
- Southern South America

7. Oceania
8. Palearctic

CHAPTER II

CONSERVATION: *EX SITU* AND *INSITU.* PLANTS VS. PEOPLE

It is argued that if ecosystems are allowed to be kept intact and materials and energy flow unhindered through the ecosystem, then conservation of the diversity of its species and the latter's genes is automatically done. Without suitable ecosystems and dynamic ecological processes, genetic or species diversity in isolation may be nearly worthless. As already stated, ecosystem conservation is coarse tuning; only after it does fine tuning at species and gene levels become possible and efficient. In other words, ecosystem diversity conservation is the cheapest and most effective way of conserving both genetic and species diversities. The other important advantage of the ecosystem approach in conservation is that it requires no detailed knowledge of the status and distribution of its constituent species. This method is particularly useful for conserving the tropical rain forest ecosystems, whose species diversity has not yet been adequately studied or quantified.

The major difficulty of the ecosystem approach to conservation is the problem of devising satisfactory habitat or ecosystem classification on which to base protected area networks. Another problem is that populations of threatened species which need urgent conservation steps are likely not be included in a network of protected areas. Thus there is risk that if attention is focused on the ecosystem, important biodiversity at the species and population levels may be overlooked. A third problem is that many ecosystems of the world are poorly known and understood. Also, the composition and complexity of an ecosystem can vary considerably in time and space. Attempts to reconcile both species- and ecosystem-based approaches are the needs of the time. It is better to identify areas or ecosystems of high diversity, especially in threatened species and undertake efforts to conserve such areas.

Relevance of Ecosystem Diversity as well as Services in Conservation

Almost all the recent initiatives of conservation, especially in the tropics, have been biased towards ecosystem (and species) diversity, ignoring ecosystem services. This is often justified on the ground that conservation of ecosystem diversity contributes to ecosystem services, but the question of whether diversity improves ecosystem services, still remains unresolved (Singh 2002). The biodiversity-centered approach to conservation is primarily based on giving priority to areas of high diversity .such as hot spots, centers of plant diversity, mega diversity centers etc., all of which are located only in the tropics.

But many taxa belonging to different threatened categories occur outside these areas and their ecosystems may generate a significant amount of services for humans. The arid desert ecosystems, for example, may be very poor in biodiversity, but may generate services of value. Similarly, the sea grass ecosystem is extremely poor in species diversity but highly significant in terms of productivity. Thus it is evident that ecosystem services are not related to biodiversity. It should also be emphasized that 'even to justify the conservation of biodiversity-rich areas' from an economic perspective 'there may be need to take the support of ecosystem services as incentives' (Singh 2002). It is suggested that spending time and resources on biodiversity-rich areas alone for conservation may have to be reconsidered according to people who strongly advocate the concept of having ecosystem services as the basis for all conservation programs. Further details on ecosystem conservation are provided below.

Top-down and Bottom-up Protocols for Conservation

Box 3.1: Steps involved in top down approach to conservation of biodiversity (from Gnaeshaiah *et al*, 2001).

1. Compile the spatial data on layers of the ecosystem
   a. Physical parameters such as temperature, rainfall, humidity, altitude
   b. Biological parameters such as distribution of biological diversity, endemism, threatened species, vegetation type etc..
2. Identify the landscape types

   Divide the target area into grids and assign the data layers from step 1. Using multivariate tools cluster the grids to arrive at the distinct landscape types. A hierarchical system of crunching the clusters can be adopted such that the number of landscape elements eventually handled may be decided on the basis of resources available. Stratifying the area by overlaying the physical and biological parameters can also identify the landscape elements.

   Using GIS tools map the landscape types or clusters and identify a set of large patches within each landscape type as representatives for conservation.

3. Evaluate the area for genetic and biological diversity
   a. Set up sample plots in all the selected large landscape types and evaluate them for their

genetic conservation worth.

b. Estimate the genetic conservation value: Since the genetic conservation values (GCVal) of a site that can be computed as a function of the population are not known, we suggest that the genetic conservation value of a site be computed as a sum of the genetic diversity (Gdi) weighted with the population size (Pi) of the species

Over a defined number of species as given below:

$$\sum_{i=1}^{s} GdiXpi,$$

Where S = number of species in the j_{th} plot, and GCValj = the genetic conservation value of j_{th} plots.

c. Estimate the diversity of plant species of the plots.

4.Identify areas with high conservation worth

Those with the highest species diversity and high GCVal can be mapped and the corresponding areas prioritised for conserving the genetic resources of the area.

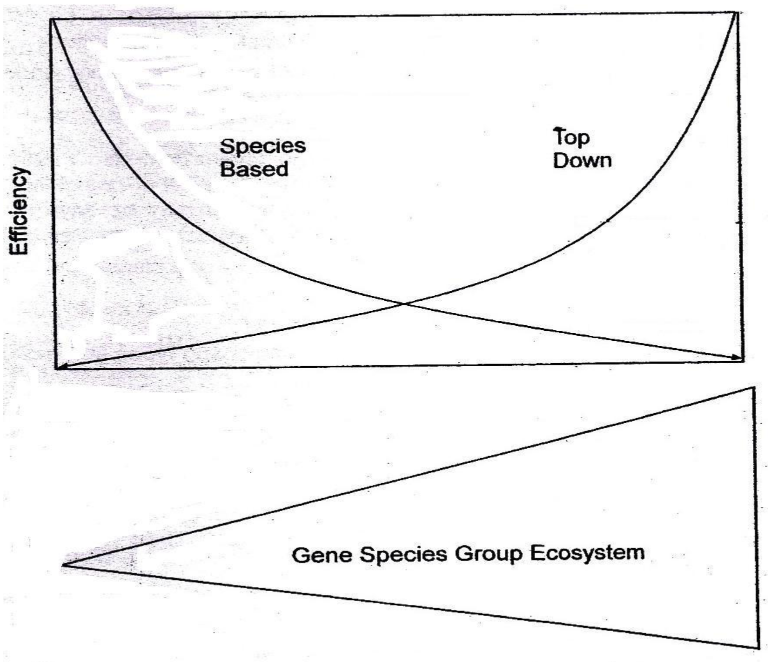

Figure 3.56: Efficiency of bottom-up land top-down approaches in conserving genetic resources. While the top-down apprpach compromises details of target species, it addresses the conservation of genetic resources of the non-target species. The bottom-up approach specifically addreses conservation the target species adapted from Ganeshaiah *et al*., 2001).

There are advantages as well as disadvantages in both species- and ecosystem-based approaches to conservation. Hence it is suggested that the two approaches be combined so as to effectively conserve both the desired species that need immediate attention and the ecosystems. Ganeshaiah *et al.* (2001) proposed two complementary approaches, viz: Top-down and Bottom-up protocols that address not only the immediate needs, but also the whole genetic resources of an ecosystem.

In the Top-down approach the major landscape elements that are likely to harbour the diversity of genetic pools of known and unknown species are identified first. Then the large landscape patches with greatest genetic diversity of a set of species and with a high level of biodiversity are identified for conservation actions. In the Bottom-up approach, pyramiding the species that need conservation attention on a priority basis is done. The various steps involved in the two approaches are shown in Boxes 3.1 and 3.2 (see also Fig. 3.56). A combination of the two approaches is efficient and cost-effective in conserving species of large areas, especially in the tropics.

***In-situ* and *ex-situ* Conservations**

Preservation of a species as a component of the functioning ecosystem, i.e., in an environment in which the species is subjected to continuing selection pressures and adaptive evolution is called *in-situ* or on-site conservation. Hence *in-situ* conservation is described as 'dynamic'(Frankel *et al.* 1995). Strictly speaking, it is the conservation of the whole ecosystem. This type of conservation of the whole ecosystem. This type of conservation has two aims: (i) to maintain economic production and (ii) to replant the ecosystem with local sources of seeds propagules. This is the most important form of biodiversity conservation for a variety of reasons.

Box 3.2: Steps involved in bottom up approach to conservation of biodiversity (from Ganeshaiah *et al.*, 2001)

1. Identifying the target groups

These could be sets of species that share common economic use and are taxonomically related.

2. Map the hot spots of species diversity and locate the viable patches

Contoursi of species diversity of the targeted grougs could be constructed based on a range of data sets on the occurrence and abundance of the species. The data sources could be forest working pians, flora, forest officer's data sets and herbarial collections (Ganeshaiah and Uma Shaanker, 1998, 1999; Ravi Kanth et al. 1999). Typically, information on the spatial distribution of different species of the group chosen is collected in a spatial database system. The study region is divided into grids of suitable size and the density of species in each grid counted. From this density data, contours of different species densities are drawn and hot spots of species richness identified. From within these identified hot spots of species diversity, patches containing the viable populations of a reasonably large set of species need to be located for estimating the genetic diversity of the species.

3. Estimating the genetic diversity and identifying the.genetic hot spots for conservation

The genetic diversity of the chosen species in these patches is estimated for further prioritization. Patches with high genetic diversity and reasonably large populations of species shall be the candidates for conservation and hence shall be identified as the 'genetic hot spots' for conserving *in situ* the genetic resources of the target group. Such genetic hot spots for different groups of plants can be integrated to eventually arrive at a network of sites for conserving the plant genetic resources of the area or region.

Among domesticates, land races cultivated in their native environment are subjected to *in-situ* dynamic conservation. Maintenance of species away from their normal ecosystem/habitat is known as *ex-situ* or off-site conservation. It is considered a means of static conservation' (as opposed to dynamic *in- situ* conservation) (Frankel *et al.* 1995). *Ex-situ* conservation is slowly becoming more important as a back-up, and sometimes as a temporary replacement, for *in-situ* conservation (Heywood 1990). The distinction between *in-situ* and *ex-situ* conservations is not always absolute and the two are in no way mutually exclusive; rather they are complementary.

As already stated, in situ conservation is the conservation of biodiversity where it currently exists. Governmental as well as nongovernmental organizations are involved in this type of conservation. Both individual species as well as ecosystems/habitats are conserved by this method, since it is impossible to have meaningful conservation of a species *in situ* outside the ecosystem of which it is an integral component. It should be mentioned, however that the mere presence of a species in a conserved ecosystem/habitat is *per se* no guarantee of its survival unless the levels of protection needed for this species are adequate. Even in areas under active *in-situ* conservation, proper management strategies are needed to maintain the viable -populations of a threatened species requiring conservation.

Both domesticated and wild taxa can be conserved *in-situ* through a network of protected areas throughout the globe (FAO 1991c). Although the problems involved in *in-situ* conservation are enormous, the results obtained this far are encouraging, in spite of the fact that the overall extent to which it conserves habitats and species, especially in the tropics, is not clearly known. A survey of protected areas 'Worldwide revealed that the *in-situ* method conserves habitats and species to a reasonably extent. Many protected areas are largely free of human activity.

Protected areas: Introduction

Areas of natural habitats/ecosystems protected under *in-situ* conservation are called protected areas. The 1994IUCN Guidelines for Protected Area management Categories (IUCN 1994a, b) define a protected area as follows: An area of land and/or sea specially dedicated to the protection arid maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means'. Protection of areas is a recent phenomenon dating back only to about a century in most countries, but several centuries in India, Thailand and China. There are many types of protected areas with differing degrees of protection, permanency and purpose. No single category of protected area can satisfy all needs and over the past many years a wide variety of protected area categories have evolved. Some have evolved to fulfill local requirements, while others, e.g. National parks, have a much broader role in conservation.

Table 3.1: he most significant types of proected area for conservation of plants (from given 1984).

Primary conservation objective	I	II	III	IV	V	VI	VII	VIII	IX	X
Maintain natural ecosystems in natural state	1	1	1	1	2	3	1	2	1	1
Conserve genetic resource	1	1	1	1	2	3	1	3	1	1
Maintain ecological diversity and environmental regulation	3	1	1	2	2	2	1	2	1	1
Provide education, research and environmental monitoring	1	2	1	1	2	3	2	2	1	1
Produce timber, forage on a sustained basis	-	-	-	3	2	-	3	1	3	-
Conserve watershed condition	2	1	2	2	2	2	2	2	2	2
Protected sites and objects of cultural heritage	-	1	3	-	1	3	1	3	2	1
Stimulate rational, sustainable use of marginal and rural areas	2	1	2	2	1	3	2	1	2	2

The confusing range of protected areas can be classified broadly into the following: Scientific reserve/Strict nature reserve, National park, Natural monument/Natural landmark, Managed nature reserve/Wildlife sanctuary. Protected landscapes and Seascapes, Resource reserves, Natural biotic area/Anthropological reserve, Multiple-use management area/ Managed resource area, Biosphere reserves, World heritage sites (natural) etc. (Mackinnon *et al* 1986). A new category of World Heritage Sites called Cultural landscapes has been recognized which acknowledges the complex interrelationships between man and nature in the construction, formation-and evolution of landscapes. Each type of protected area is stated to be particularly suited to one or many plant conservation objectives (Table 3.1). It is very difficult to distinguish one type of protected area from another as considerable overlapping exists between them; hence only the most commonly recognized protected areas are discussed here.

Today, there are over 9832 protected areas (IUCN categories I-V), including 1508 National Parks, of approximately 9.25 million km (almost the size of the USA) or about 8.2% of the Earth's land surface. A further 40,000 smaller protected areas cover another 5% of the land area (Duthie 1997; McNeely 1994; UNEP 1995). The goal recommended by IUCN, however, is preservation of a cross-section of all major ecosystems to the extent of 13 million km^2, or about 10-12 % of the Earth's surface.

Biosphere Reserves and National Parks: Introduction

Protection of an ecosystem in the form of a Biosphere Reserve dates back to just a century and half. Originally these reserves were created not with the intention of protecting biodiversity, but as tourist attractions and for their aesthetic appeal; they protected the plants and a living there only incidentally. For example, in North America, the world's first National Park was established in 1847 at-Yellowstone, with the initial emphasis on recreation rather than conservation. In the UK, the establishment of Nature Conservancy in 1949 was instrumental popularizing the already-existing National parks and Biosphere reserves as means of in-situ conservation. Only in the last 50 years hall Biosphere reserves and National park systems been exclusively created to retain biodiversity and ecological processes and hold great promise for efficient conservation of habitats/species. THE emphasis in such efforts was on conservation of ecosystems and conservation of species ail components of ecosystems.

Nature Reserves are now developed across the world for one or more of three primary biological motivations: (i) To preserve large and functioning ecosystems; in such an effort, the resources are expected to provide adequate conditions for the long-term survival of evolving ecosystems, (ii) To preserve biodiversity with a view to conserving the maximum possible number of species and communities, (iii) To protect particular species or groups of species of special interest, which are especially threatened. These three goals and the reserve types developed to fulfill them are not mutually exclusive; one can take care of the one or both of the other two. The more a reserve can take care of all three goals, the more desirable and successful it will be.

A fourth motivating goal may be added, namely the perpetuation of plants for continuing and sustainable harvest. In addition to these four goals, other cogent objectives should be added (McNeely *et al.* 1987).

- To maintain and promote genetic diversity,
- To serve the requirements of education and research,
- To conserve-water and soil,
- To manage wildlife,
- To serve as sites of recreation and tourism,
- To protect social and cultural heritage,

- To maintain scenic beauty and aesthetic integrity,
- To promote options for the future,
- To promote integrated development within the reserve and between reserves.

Biosphere reserves will also play an increasingly important role in the conservation and utilization of wild relatives of crops, although the resource value of such wild relatives available in most reserves of the world is still poorly known. Less than a third of the world's biosphere reserves have been inventoried for their component species and the status of their populations. There is no systematic documentation of wild relatives of useful taxa and land races of cultivated plants in these reserves. Further, only a few of the world's biosphere reserves are in the centers of crop origin or in regions of great species diversity. However, even the scant data available indicate that well over 20% of the reserves have populations of wild relatives of major crops, and with better documentation and inventories this percentage is likely to exceed 50. It may be further stated that less than 10% of the total species and allelic diversity of the major crop gene pools are currently maintained *in situ* in Bioreserves. Of these, only a small proportion is conserved at adequate levels to withstand imminent threats to them as well as to meet the needs for germplasm for breeding programmes.

Land races located in reserve areas are to be conserved in their home environment as a part of dynamic conservation, since once displaced by improved cultivars, their *in-situ* conservation, as a deliberate measure, becomes very difficult. True, any attempt to retain 'primitive farms' that contain land races for a long term in a radically changed social and technological environment would be self-defeating. However,- one car propose to establish 'Crop Reservations', areas or 0.56 to 1 ha in size, wherein a land race could be maintained under the management of a local agricultural officer. This is practiced in Iran and Turkey even today. These can be allowed to be subjected to environmental changes resulting from agricultural development through the use of fertilizers, pesticides, innovative technologies etc as well as the genetic changes mediated both natural hybridization, mutation and natural selection, further details are given below.

World biosphere reserve programmes

The Biosphere Reserve programme is a worldwide one of international scientific co-operation. It combines biodiversity conservation with scientific research, monitoring of environment, training- and demonstration in bio resource management, environmental education, and local co-operation and coordination. The real purpose of this programme is to promote a harmonious 'marriage' between conservation and sustainable development. The Biosphere programme was essentially the outcome of the efforts of UNESCO; this organization started the Man and Biosphere (MAB) programme (Gregg 1988). The past role arid future directions of this programme were discussed in the International Conference, on -Biosphere Reserves in Seville, Spain inl995. The conference adopted 10 key directions to develop MAB's three main functions of conservation, development and logistic support. As of June 1995, there were 324 reserves located in 82 countries covering some 2415,000 km^2. The most important among them are: Dinghushan Biosphere Reserve of South China, Beni Biosphere Reserve of Bolivia, Manu Biosphere Reserve of Peru, Guatopo Biosphere Reserve of Venezuela, Kwakwani Reserve of Guayana, Luquillo Reserve of Puerto Rico, and Virgin Island Biosphere Reserve of St John.

Design of biosphere reserves

The design of a Nature Reserve is very crucial to its success (Frankel and Soule 1981; Margules and Nicholls 1988; Margules *et al.* 1982; May 1975; Spellerberg 1991). Much discussion has ensued about reserve designs, due largely to lack of clarity or Precision as to the aims of particular reserves and their perceived lifetime. The aims, already mentioned above, are mainly dictated by an amalgam of ecological, economical social and political compulsions.

Six critical issues determine the success of a reserve which must perforce be seriously considered while designing it, namely: (i) reserve size, (ii) inclusion of spatial and temporal heterogeneity and dynamics, (iii) Ideal geographic context, (iv) connection of various reserves (i.e., contiguity) on a regional basis, (v) regard for natural landscape elements and (vi) creation of zones of different uses within the reserves (Given 1996).

(i) Reserve size: Ideally, reserves should be large. Larger reserves are much better than smaller ones for the following reasons: They maintain individual species, biodiversity and ecological functions, especially the homeostasis of ecosystems, energy cycle, food chain and trophic levels. Larger reserves will often contain the minimum viable population (MVP) size of constituent species; they will maintain genetic diversity better; they do not have edge effects they will be able to minimize the impact of external variables and to accommodate disturbances much better. In the past, the size of many Nature Reserves and National Parks was; determined primarily on aesthetic and ecological grounds rather than genetic considerations of those species especially requiring conservation. A good example is *Eucalyptus globulus* in Victoria and Tasmania, where the stands retained in reserves are genetically less desirable (Eldridge *et al.* 1993).

Box 3.3: Guidelines for selecting a system of tropical forest habitats for protection (from McNeely *et al.* 1987)

Step 1: Survey

Step 2: Establish criteria

A. Ecological criteria

(1)Dependency

(2)Naturalness

(3)Uniqueness

(4)Diversity

(5)Integrity

(6)Representativeness

B. **Scientific and educational criteria**

(1)Convenience

(2)Monitoring benchmark

(3)Research history

(4)Demonstration

(5)Process relationship

(6)Awareness

C. **Social and economic benefit criteria**

(1)Economic benefit

(2)Social acceptance

(3)Recreation

(4)Tourism

(5)Landscape

(6)Demonstration

D. Pragmatic criteria

(1) Urgency

(2) Opportunism

(3) Management

(4) Feasibility

(5) Availability

Step 3 : Select areas to be included in the system ----

Step 4 : **Establish the system**

Step 5 : **Manage the individual protected areas**

How large should a nature reserve be? This is a highly debated question. The size of a reserve should be based on computation of the MVP of that/those species which is/are the chief target(s) for conservation in it through population viability analysis (PVA). Almost all computations made to date for reserve size have been based on animals, especially larger carnivores. Claims such as those of McNeely *et al.* (1990) that 'many plants can survive for several centuries in a forest niche scarcely larger than the diameter of its leaf rosette give a false notion about the total area requirements of plant species, Since such claims do not take into account all aspects in the life cycle of a plant species. In fact, computation of reserve size based on MVP of plant species is the need of the hour. A critical survey of all world reserves revealed that they vary markedly in size and degree of protection. Sizes ranges from about one hectare to millions of hectares, i.e., are extremely disparate. A survey of 919 of the world's more temporally significant Nature Reserves showed that 76% for were less than 100,000 ha in area and only 3.5% exceeded a million ha. In Australia, for example, there are 3429 reserves covering 6.5% of the continent's total land area. Seventy-four per Cent of these reserves are less than 1000 ha in size, while only 2.6% exceed 100,000 ha; the nine largest reserves comprise 37.5% of the protected area (Given 1996).

(ii) Spatial and temporal heterogeneity and dynamics: Spatially and heterogeneous areas are better suited developing a reserve than homogeneous areas, if the goal is to maintain very high biodiversity. The basis for this fact is that nature is dynamic and changes over time and space through biotic and abiotic disturbances and that a spatially heterogeneous reserve better accommodates these disturbances than a homogeneous one by offering every species a diversity of habitat types at any given point of time. If a habitat patch is changed or disturbed or otherwise becomes unsuitable for a given species, other appropriate habitat patches may be available for colonization in a heterogeneous reserve. Heterogeneity also promotes the occurrence of meta populations of a species.

(iii) Ideal geographic context: Context refers to the nature and location of habitat patches within a reserve as well as in the larger landscape of the reserve. Within the reserve, each habitat patch is spatially located in such a way that there will be movement of organisms from one habitat patch to another. At the total landscape scale, the entire reserve functions in the context of a surrounding, non-reserve area of the landscape, this can have critical consequences, both positive and negative, for the reserve.

(iv) Connection of different reserves: Reserves need to be contiguous so that they can maintain the overall integrity of the physical environment and the basic biogeochemical processes of the region in question. Reserves can be made contiguous through corridors, which are strips of areas similar to reserves connecting two or more of them. These corridors allow movement of species and thus recolonisation. Corridors are believed to counter the fragmentation effects of reserves, which are too small to keep MVP of many species. Corridors also help in reducing erosion by wind and water, in providing shelter to living organisms and in increasing the aesthetic beauty of the landscape (Hobbs 1992). Corridors should also function as viable habitats similar to reserves (Simberloff *et al.* 1992). However, adequate data are not available to categorically assert that corridors play a significant role in the migration of species across the landscape.

(v) Natural landscape elements: Natural landscape elements include such features as valleys, drainage basins, ridges, streams ecotones, slopes, canyons, habitat peninsula any other distinctive feature. The more the diversity of natural landscape features, the more enhanced the value of a reserve. Any modification of the natural elements, such as road lying, highways and railway lines agricultural fields, timber lands, industries and human dwelling will make the reserve inferior.

(vi) Creation of zones within a Reserve: The protected Nature Reserve should have a central core with suitable habitats and landscape elements and a buffer zone to absorb edge effect. Edge effects include changes in temperature relative humidity and light, more exposure to wind, elevated levels of tree mortality, increased leaf fall and decrease in population size of the constituent species. In very small protected areas the entire area, in reality, becomes an 'edge'. Edge effects are particularly important for threatened taxa (Janzen 1986). The more widely adopted technique for minimizing edge effects and maintaining core areas is to establish buffer zones around the reserve. These areas may be defined as areas peripheral to reserves which have restrictions placed on their use to give an added layer of protection to the Nature Reserve itself and to compensate local tribal's and villagers for loss of access to core areas of the reserves (Mackinnon *et al.* 1986).

Although different kinds of buffer zones are recognized (Fig. 3.57), two main types known to serve rather different functions are important 'Extension buffering' extends habitats of the core area into the buffer zone, allowing much larger populations to survive than may be possible in, the core area alone. It is particularly useful for small populations of extremely rare species. Socio-buffering' allows activities such as raising of crops or harvesting of bio resources from the reserve in such a way as to discourage use of the protected core area by people native to the reserve area who traditionally use these resources. In other words, these activities are allowed in the buffer zone to compensate for loss of traditional harvesting rights and privileges in core areas (Hanks 1984; Oldfield 1988). Since local people disturb the core zone, buffer zones can provide both biological and social benefits without the imposition of mandatory restrictions (for details).

The shape of the reserve area should be compact with biologically meaningful boundaries. Areas should contain year-round habitat requirements for animals associated with target plants, especially the essential pollinators/dispersers. Total isolation of one habitat from another should be avoided: Allowance should\be given for manipulative management of the reserve.

Biological aspects of Reserve design: Over the last five decades, emphasis has centered on size, shape and other physical aspects of serve design, largely ignoring-the biological aspects. True, biogeographic ideas and theories dominated the physical aspects of reserve design, which are also paramount in assessing the biological of reserve design. The most Celebrated dynamic equilibrium theory of island biogeography (MacArthur and Wilson 1963, 1967; Preston 1962) was extended to reserves because of the obvious analogy between true islands and reserves, which are 'islands' of natural vegetation in an otherwise 'unnatural' id hostile landscape (May 1975).

Just as for true islands, for reserves also the precise number of species at equilibrium depends mostly on size of the area at their disposal. This is termed the area effect. Equilibrium additionally depends on the distance from the source of immigrants. This is termed the 'distance effect' (Frankel and Soule 1981). Both effects profoundly influenced application of the island geography theory to the design of nature reserves (Roche and Dourjeanni 1984). Some authors pointed out, however, that often aspects of the theory have been uncritically accepted and applied to reserves with no serious thought given to the differences between true islands and reserves (Spellerberg 1991; Wright and Hubbel 1983). This objection notwithstanding, the island geography theory has had a profound effect on the design of reserves for conservation.

The major problem in reserves meant for conserving a single species or a group of selected taxa is that any effort to manage the reserve too intensely for the selected species will result in the general decline of its total biodiversity. This may even lead to the loss of particular components of biodiversity. If, on the other hand, the reserve does not receive targeted approach to management, the specific species may get lost and the reserve becomes vulnerable to contamination from gene flow and invasion of inferior elements. Hence a judicious combination of strategies to safeguard both targeted species and the entire biodiversity of the reserve should be practiced.

Vest Pockets and Garrison Reserves

Lands with recognized economic value for alternate uses usually have smaller or fewer reserves. Such reserves are termed Vest Pockets and Garrison Reserves. They are very small, sometimes only a few hectares in extent. They can be" made to survive for a longer time only with very intensive management care. In many places, these reserves represent the small remnants of populations or natural communities. The difficulties in managing small reserves for conservation are: (i) Lack of high level diversity initially. To achieve this through intense management in the long term is also difficult, (ii) They suffer from greater impact through edge effects, (iii) They are very expensive to maintain because of the intensive management required.

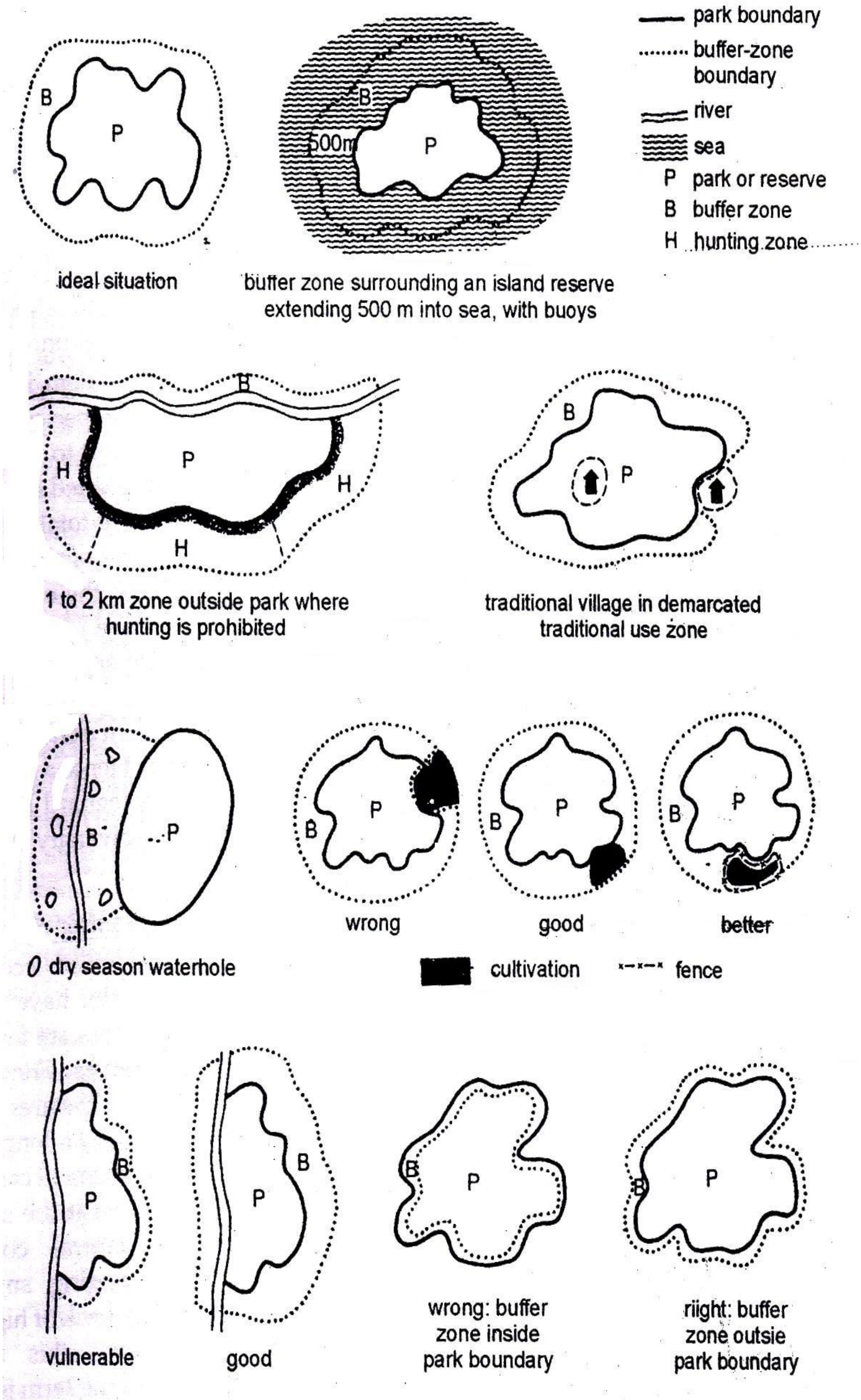

Figure 3.57: Different kinds of buffer zones for protected areas (from Mackinnon *et al*., 1986).

However, several smaller reserves in an area can be brought under a network for conservation management, (iv) The most serious problem is that adjacent land use is very different from that in the Reserve. In several countries, small reserves may be the only type available for conservation or only smaller reserves feasible due to compelling cultural social, political and/ or economic factors.

To what extent have protected areas established and maintained so far served their true function of protecting and conserving biodiversity? Unfortunately, too little data has been gathered to answer this question satisfactorily. A recent study done by Bruner *et al.* (2001) is worth mentioning, however. They assessed the anthropogenic threats to 93 protected areas in 22 tropical countries and found that the majority were not only successful in stopping land clearing and other efforts at ecosystem damage, but even showed significant recovery of natural vegetation.

It is very essential to remember that great biodiversity exists even outside protected areas. This understanding forces us to realize that there is an absolute need to adopt abroad landscape or bioregional approach to conservation and management of biodiversity (Heywood 1997b). It must also be pointed out that to date very little effort has been put into conservation efforts outtside protected areas.

On-farm and Home Garden Conservation

On-farm Conservation involves the maintenance of traditional crop varieties or cropping practices and systems by farmers within traditional agricultural systems. The crop varieties maintained 'on-farm' are often known as land races. The farmers sow and harvest the crops regularly and every season keeps aside a portion of the harvested seeds for resowing. This ongoing practice has safeguarded land races of several crops highly adapted to the local environment in many instances these crops contain locally adapted alleles that have -proved very useful for specific breeding programmes. A detailed analysis of on-farm conservation throughout the globe showed that seed-propagated crops (such as seed and grain crops, vegetables, forages and fodder species); vegetatively propagated crops (such as potato, sweet potato; yam, cassava, taro land *Xanthosoma)* and even wild and semi cultivated species were conserved as land races.

It is true that land races yield much less than modern cultivars but on-farming conservation ensures the protection and preservation of ancient land races and wild species for posterity. Therefore, the traditional farmer/tribal person growing such land races must not only be helped with subsidies, but the land races traditionally cultivated by him should be continuously protected and monitored. Jana (1993) went further and stated that one should eschew the notion that *in situ* conservation of land races is only for safeguarding breeding materials; it should be practised for its own sake.

However, undertaking such conservation steps poses a challenge in traditional areas 'without a return to or the preservation of traditional cultural systems, which may be unacceptable or impracticable under political systems' (Qualset *et al.* 1997). Most traditional agroecosystems are under the process of modernisation to varying degrees in different' parts of the world. A few "selected cases of ongoing maintenance of land races by local farmers may be mentioned here: land races of potato in the Tulumayo Paucartombp Valleys of the Central Andes of Peru, of maize in southern Mexico, of wheat in western Turkey and Italy, or of rice in the Chaing Mai Valley of Thailand.

Home Garden Conservation is a smaller-scale conservation effort made on plants-grown in home, kitchen or back yard gardens. Most of these taxa are vegetables /fruits or ornamentals. These often have indigenous germplasm in the form of land races, obsolete cultivars and rare species (Hawkes 1983). For example, Hawkes (1983) listed 45 species of cultivated and 25 of wild medicinal taxa conserved in such gardens in a village in Central Java. In Mexico, the Huastec Indians manage several home gardens, which form the place for more than 300 species (Alcorn 1984). Esquirel and Hammer (1992) described the role of such gardens, called *Conucos*, in Cuba; these are relatively larger gardens where the traditional Cuban farmers maintain local cultivars of crops.

For conservation of land races and home garden taxa, incentives must be provided. The provision of subsidies for farmers cultivating land races has already been mentioned. In addition to this, the following other incentives are suggested (Qualset *et al.* 1997). (i) Perverse incentives already being given for conservation of modern crop varieties should be discontinued, (ii) Amenities in rural and tribal areas should be enhanced, (iii) The development of niche markets should be encouraged, (iv) Facilities to expedite commercialization of the products of land races should be built, (v) Amateur conservationists, farmers and landowners, natural resource groups and scientists should be encouraged to conserve land races, (vi) Government and other institutional interventions should be minimized, (vii) Detailed scientific studies (especially population genetic studies) of land races should be done, (viii) Breeding programmes in land races should be established.

Ex-situ *Conservation*

Ex-situ conservation can be followed for both wild plants and domesticated crops. While the first section under this heading is concerned mainly with domesticated crops, all subsequent sections are applicable to both wild and domesticated taxa.

Germplasm Collections

These refer to assemblages of genotypes or populations often maintained as research materials for plant breeders, crop evolutionists, ecogeographers, taxonomists, phytopathologists etc. Germplasm collections consist of samples of domesticated taxa and their wild relatives, which are maintained either *in vivo* in the form of plants, seeds, tubers and other propagules or *in vitro* in the form of single cells to parts of whole plants.

Phillipe de Vilmorin at Verrieres near Paris attempted the earliest substantial collection of a crop plant, wheat, in the middle of the 19th century. Other collections, not only in wheat but other crops as well, followed closely in England, Germany, Sweden and Australia. These collections consisted mainly of land races obtained from different scientists, breeders or traditional farmers in different countries However, the first systematically assemble germplasm collections were the result of several plant exploration expeditions conducted in the 1920s and 1930s by N.I. Vavilov and his colleagues at the USSR Institute of Plant Industry, now known as the VaVilov Institute of Plant Industry (Vavilov 1949-50).

Inspired by Vavilov's initiatives, systematic explorations and collections of germplasms intensified, particularly in the areas identified by Vavilov as centres of genetic diversity. For example, 34 potato collection expeditions were undertaken by Hawkes (see Hawkes 1970) in South America between 1925 and 1967. Research institutions, in particular international agricultural research centres, played an increasingly important role in germplasm collections of many crop taxa. Many individual scientists were responsible for establishing very good germplasm collections of crops such as tomato, safflower, okra, cucurbits etc. As a result, there are now about 6.2 million accessions of 80 different crop taxa stored in 1320 gene banks and related facilities in 131 countries (FAOW96a). Of these, wheat germplasm accessions constitute 14%, rice-7%, maize 4% and other crops 75%.

The institutions involved in germplasm collections are different, are operating in different geographic locations and-are working with different purposes in mind. The same is true of individual scientists. Hence, there are large differences in the origin and purpose, size and geographic or taxonomic coverage, and the biological status of the material between the germplasm collections attempted and executed so far. Nonetheless germplasm collections often contain unique and very valuable genetic materials worthy of being identified, maintained and exploited. Germplasm accessions, individually as well as collectively, are not only to be made available to all kinds of users of the world's genetic resources presently, but also to be conserved for the use of future generations.

What should be the size of the plant germplasm collection? No single figure can apply to all collections or to all crops. However, it is recommended that 10-100 is suitable to a collection of cytogenetic stocks of species, 10,000 and above for a world collection of any major crop such as wheat or rice: Collections should represent and cover all possible variations that could be exploited for crop improvement and consequently the larger the collection, the more likely it will include all possible genetic information. Yet the prohibitive cost involved imposes limits on the discriminate accession of germplasms.

Redundancy is a major problem in germplasm acquisitions. This can be avoided or minimised by setting up a core collection versus a reserve collection (Frankel and Brown 1984). THE former refers to a minimal set of collections that more than adequately represent the genetic diversity present in the total collection. The latter refers to an accession not selected for the core set but nevertheless conserved. Further details on these collections can be found in Brown (1989).

Lastly it should be emphasized that germplasm resources, although primarily intended for breeding and related purposes, have been/may be used to unravel evolutionary processes and taxonomic affinities, to identify centers of origin or diversity of crops and to discover the distribution patterns of genetic **va**riability or particular features or genes, and to relate these patterns to environmental variables to which the plants are subjected.

Botanical Gardens

Although a satisfactory definition is still wanting, a botanic garden can be broadly defined as a place of collection of living plants grown for educational, recreational, economic, medicinal or scientific purposes. A botanic garden is the most important form of *ex-situ* conservation). The most widely known function of botanic gardens is to assemble and maintain a diversity of plant species in the open or in greenhouses for reference and study. Botanic gardens conduct or facilitate research in diverse aspects of plant science, especially in taxonomy. They have a long history of concern for taxa of economic value, dating back to the medieval gardens of the 14th century of Europe and further back-to the 7 th century "Nandavanas" or "sacred groves" of India. The first recorded European botanic garden was probably the one established in 1545 at the University of Padua in northern Italy, which even in 1591 was reported to contain around 2000 species (Given 1996). In India, epigraphical inscriptions speak of - well-established temple gardens *(Nandavanas* or sacred groves) even by 7th century A.D. (Krishnamurthy 1999; Swamy 1973). From the 17th century onwards botanic gardens have played a significant role in the introduction and exchange of useful plants between Europe, the Americas, Africa and Asia.

It has already been noted that botanic gardens form the single most important institution involved in the *ex-situ* conservation of wild plants. The very first comprehensive attempt to involve world botanic gardens in conservation was made in 1953 at an International Colloquium of the Sub-Committee of Botanic Gardens of the Union of Biological Sciences (IUBS). As a result, in the next year the International Association of Botanic Gardens (IABG) was formed. This was followed by the compilation of an International Botanic Gardens Directory (see Larsen *el al.* 1987). In 1968, the late Ronald Melville used information drawn from world botanic gardens in preparing the International Red Data Book. In the Kuala Lumpur symposium of 1974, the roles and goals of tropical botanic gardens were discussed at length. Meanwhile, the Threatened Plants Committee (TPC) entrusted the plan for conservation of threatened taxa to the IUCN Botanic Gardens Conservation Secretariat (BGCS; now BGCI). The BGCS, first through a conference held at the Kew Gardens in 1975 (Simmons *et al.* 1976), emphasized the need for conserving threatened taxa in the world botanic gardens. The first International Botanic Gardens Conservation Congress was held at Las Palmas, Canary Islands in 1985, where planning for conservation of taxa through the botanic garden was further strengthened. This conference examined critically the role of botanic gardens in the context of a world conservation strategy and .recommended the establishment by IUCN of BGCS 'to co-ordinate and monitor the plant conservation activities of the botanic gardens of the world' 0ackson 1989). The BGCS was set up by IUCN on the first of January 1987, which subsequently became an independent body in 1990.

The second International Botanic Gardens Conservation Congress was held at Ile de la Reunion in 1989. A drastic change in direction was 4ntrodueed in. this congress; the major emphasis shifted to germplasm conservation in the botanic gardens, with plants of economic value principally targeted for conservation over threatened and endangered species. The BGCS was advised to give priority to monitor and promote research into conservation of useful taxa, including germplasms of major and minor crops 0ackson 1989). However, propagation and reintroduction of rare and endangered species are to be actively encouraged but with lower priority. This in reality meant the continued conservation of around 35,000 endangered species in botanic gardens, in addition to greater effort on 15,000 or so economically important species including a number of medicinal taxa (Heywood 1991a). This, according to Frankel *et al.* (1995), amounted to a 'north-south" distinction between the two contrasting strategies of botanic gardens. The BGCS thus has to lay greater emphasis in the tropics of the**.** Southern Hemisphere on threatened species which have greater economic value (the south strategy), while in the Northern Hemisphere emphasis is to be on endangered species irrespective of their economic value (the north strategy). This new Botanic Gardens Conservation Strategy (WWF/IUCN/BGCS 1989) was elaborated further by BGCS. It recommended botanic gardens to participate in *in-situ* conservation, with small reserves of 5 to 50 hectares solely entrusted with the conservation of specific individual species with their genetic diversity. The BGCS now maintains the database *on ex-situ* conservation assembled by the World Conservation Monitoring Centre (WCMC), and records about 60,000 rare and threatened plant species held in about 400 institutions worldwide (Jackson 1991).

There are many kinds of botanic gardens and arboreta (BGCS 1989): (i) traditional, state supported gardens, with associated herbarium and laboratories (e.g. Berlin, Kew, Bogor "Peradeniya); (ii) municipal or civic supported sometimes with associated herbarium and laboratories, normally open to the –public (e.g. Gothenberg, Glasgow, Nantes); (iii) university gardens with an associated herbarium and laboratories, usually open to the public (e.g. Cambridge, Berkeley/Hamburg, Montpellier); (IV) private, often with some state support, with an associated herbarium and laboratories, invariably open to public (e.g. Missouri Botanical Garden, Fairchild Tropical garden at Miami); (v) private, without state support, usually lacking a herbarium or laboratory (e.g. Les Cedres, Maurimurta); (vi) Government/State arboreta with an associated herbarium and laboratories (e.g. US National Arboretum) or without herbarium (e.g. Westonbirt); (vii) university arboreta with an associated herbarium and laboratories (e.g Arnold Arboretum); (viii) private arboreta, with or without herbarium or laboratories (e.g.Hilliers, Morton arboretum, Bickelhaupt); (ix) botanical-zoological gardens/ parks (e.g. Hongkong, Wilhelma Stuttgart) and (x) agrobotanical gardens (e.g. Godolio, Gatersleben, Castelar).

There are more than 1500 botanic gardens/arborata throughout the world (BGCS 1989; UNEP 1995) and this number should have increased further in the past few years. Of these 1500 gardens, about 800 were believed to be very active in plant conservation process. Of these 582 have a seed bank facility? All these gardens together at the time of survey contained well over 3 million plant taxa, excellent proof of their importance in active plant conservation programmes at that time itself. There is considerable imbalance in the global distribution of botanic gardens (Table 3.2). Europe has 540 gardens, USA 451 (Heywood 1990), Africa 82, South America 66 and India 79 (8 large and 71 smaller gardens; Chakraverty and Mukhopadhyaya 1990; Nayar 1997; accounting for about 8500 taxa).

Most tropical countries, which account for more than 90% of the world diversity, have very few botanic gardens. It is gratifying to note, however, that many of the most recently created botanic gardens have been housed in tropical countries. The collections maintained in botanic gardens are very diverse. 0rchids, succulent's bromeliads. Bulbous taxa and temperate trees are particularly well represented. Tropical trees, epiphytes, carnivorous taxa, palms, cycads etc. are rather poorly represented.

Table 3.2: Geographic distribution of botanic gardens and arboreta by region (from Heywood 1987).

Region	No. of gardens	No. of Arboreta	Population
Europe	392	64	500,899,461
Former USSR	121	34	266,674,000
South-Wst Asia	14	2	134,508,085
South & South east Asia & Oceania	107	50	1,322,957,070
Australia & New Zealand	47	8	18,125,857
China, Japan, Mongolia & Taiwan	66	13	1,144,269,000
North Africa	10	-	89,170,000
Tropical Africa	28	2	329,846,340
South Africa	14	1	25,590,000
North America	98	92	252,219,951
Middle America	36	-	93,133,378
South America	51	1	236,979,117
Caribbean	20	-	28,764,205

The problems encountered by botanic gardens are innumerable. Many botanic gardens, especially in the tropics, are poorly financed and badly organised and managed. Trained technical persons are wanting. Also, a large, percentage of plants growing in such gardens is of low conservation priority. In many cases the genetic diversity maintained in these gardens (also in some well-organised gardens) is inadequate for conservation purposes. The majority of endangered species are tropical while the well-organised gardens are predominantly located in temperate regions; these temperate gardens have taken up much of the burden of preserving tropical species in greenhouses with simulated tropical climate or in the form of seed storage.A simple, most effective and least costly way to overcome this problem according to Raven (1976), is to ensure the perpetuation of endangered species by introducing them successfully into the horticultural trade; botanic gardens can take up this *i* introduction very seriously. Already, endangered plants in the wild such as *Ginkgo biloba, Franklinia alatamaha, Encephalartos woodii, Swietenia humilis, Dracaena draco* and others have been perpetuated in this manner. Another way of resolving this problem is through effective coordination between botanic gardens situated in different parts of the globe. The BGCI is already coordinating very well by disseminating information, promoting *ex-situ* conservation of threatened plants by fixing priorities, providing technical guidance and data as well as supporting .weak-gardens financially and otherwise. BGCI has a worldwide membership of about 320 botanic gardens.

Information is still scant regarding the impact of botanic garden management on the actual conservation status and survival of threatened species. There are several known cases of threatened species surviving exclusively due to botanic gardens (Falk 1987), for example *Sophora toromiro* from Easter Island and *Commidendron rotundifolium* from St. Helena. Some other taxa that have become extinct in the wild but are still maintained in botanic gardens are listed in Table 8.4. As mentioned elsewhere, the mere presence of a species in a botanic garden is no guarantee for its conservation, however. Hurka (1994) argued that one significant way wherein botanic gardens could promote conservation is through education and through their influence on public opinion. Botanic gardens should give greater prominence to local flora. A good example for this type of service turned out in conservation is the Missouri Botanic Garden.(St. Louis, USA), which through the establishment of the Centre for Plant Conservation in 1984 in the garden has already collected and maintained all the endangered species of the USA in the living state, supplemented by a seed bank.

Seed Banks

A seed bank is a collection of seeds stored in a viable state for posterity. This term is also used in a different context,, i.e., accumulation of un germinated seeds usually found in the soil (Archibold 1989). Soil is a kind of gene bank to which seeds are added year after year. The number of seeds that accumulate over the years can be prodigious, as seen in a study made in Denmark. One block of top soil—1 m square and 20 cm deep—yielded roughly 135,000 seeds, of which about 50,000 were living and could germinate under the correct conditions (Koopowitz and Kaye 1990); such an accumulation was labeled a Natural Seed. The artificial seed bank is a very good device for conservation of plants. Conservation is both safest and cheapest if life processes are reduced to a low level, and seed preservation in seed banks fulfils this requirement admirably. Conservation through seed storage aims to preserve as much as possible the genetic integrity of individuals or populations of a species. Although frequencies of genotypes or alleles may undergo inevitable changes due to storage, gene or allele erosions are minimised, a recombination with alien material is avoided. Preclusion or reduction in natural selection genetic drift, natural hybridization and destruction by parasites or loss through human error are also ensured. No other genetic effect has been observed.

A seed bank is one of the most efficient methods of *ex-situ* conservation for sexually fl reproducing species. Seeds suitable for long-term storage are termed orthodox, conventional or ' desiccation-tolerant. Such seeds can be stored for a long time without substantial loss of vitality and without much genetic changes (Roberts 1975, 1989). Roberts (1975) defined orthodox seeds as seeds for which the viability period I increases in a logarithmic manner as one reduces the storage temperature and the moisture content of the same'. Seeds, which cannot be stored in seed banks under the given conditions, are termed recalcitrant. Jackfruit, citrus, avocado, coffee, tea, maple, cinnamon, nutmeg, oak, chestnut, mango, cocoa, coconut and rubber, belong to this category. It is difficult to conserve recalcitrant seeds. It is estimated that 20% of the world's total plants produce recalcitrant seeds that do not survive in low temperature and/or dehydrated conditions.

They have no natural, dormancy and die if not allowed to germinate immediately. It has also been found that the majority of orthodox seeds are either from temperate regions, where dormancy is enforced cold winters, or from arid regions where dormancy is enforced by hot and dry climate. Rain forest seeds are often recalcitrant. Among orthodox seeds, much importance is often given to small seeds, which occupy less space. The FAO constituted a panel of experts on plant exploration and introduction, which formulated certain standards and procedures for storage installations meant for long-term seed conservation (FAO 1975). The recommended conditions for seed storage are -18°C or less temperature, use of airtight sealed containers, and seed moisture content of 5-2%. The seed bank needs proper and continuous power supply.

Table 3.3: Some taxa 'extinct in the wild' but conserved in botanic gardens (data from IUCN/WCMC and Michael Maunder, in Prance 1997)

Sl. No.	Taxon	Native Country
1	Anthurium leuconeurum	Mexico
2	*Arciostaphylos uvaursi* ssp. *loebreweri*	USA
3	Bromus verticillatus	UK
4	Calandrinia feltonii	Falkland Island
5	Ceratozamia hildae	Central America
6	Commidendrurrfrotundifolium	St. Helena
7	Cosmos atrosanguineus	Mexico
8	Erica verticillata	South Africa
9	Encephalartos woodii	South Africa
10	Franklinia alatamaha	USA
11	Graptopetalum bellu	Mexico
12	Helichrysum selaginoides	Tasmania
13	Lysimachia minoricensis	Minorea
14	Opuntia lindheimeri	Mexico
15	Paphiopedilum deletanatii	?
16	Sophora toromiro	Easter Island
17	Tecophilaea cyanoorocus	Chile
18	Trochetiopsis erythroxylon	St. Helena
19	Tulipa sprengeri	Turkey
20	Dombeya aoutangula	Rodrigues
21	D.mauritiana	Mauritius
22	*Vemonia shevaroyensis*	S. India

* Extinct in wild, while a single tree is growing in the botanic garden cum orchidarium ot the Botanical Survey of India at Yercaud, Salem, Tamil Nadu, S. India.

Medium-term storage can be affected at 6l'°C (Cromarty *et al.* 1982; Dickie *et al.* 1984; Ellis *et al.* 1985; Hanson 1985; IBPGR 1985). Storage at the temperature of liquid nitrogen has given encouraging and problem-free results. It is also less costly than the conventional seed storage. However, the moisture content needs to be strictly controlled. Orthodox seeds can be kept under storage for very long periods at sub-zero degree centigrade, if previously dried to about 5 to 8% moisture content. Although longevity varies from taxon to taxon, orthodox seeds can be stored for 5 to 25 years at 0 to 5° C (medium-term storage) or for up to 100 years if stored at -10 to -20 (long term storage). The basis for this increased period of viability with decreased temperature treatment is as follows (Koopowitz and Kaye 1990): For every 5°C drop in temperature, the life of the seed will double. For example, onion seeds with 10% moisture are viable for 16 weeks at 35°C, but will live for 78 years at 0°C.

Dropping the temperature further to -15°C would enhance seed longevity to 624 years (Koopowitz and Kaye 1990). Similarly, the life of a seed will double with each 1% decrease ih water content. However, a minimum of 4% water content appears to be required by seeds to remain alive. Keeping the foregoing in mind, when both temperature and water content are judiciously reduced, the two factors multiply the life span of a seed. For example, when temperature drops by 5°C and water content decreases by 1%, the seed lives four times longer (Koopowitz and Kaye 1990). The actual reason for failure in storage of recalcitrant seeds is that a decrease in moisture content of such seeds infringes viability; such seeds, at maturity, have a moisture content of 12 to 31% and any reduction renders them non-viable (see Chin and Pritchard 1988).

Long-term seed storage requires conduction of regular regeneration tests in stored seeds to monitor their viability. The frequency of their germination/regeneration depends on their initial viability, rate of loss of viability due to storage, and storage conditions. The minimum requirement for each regeneration test is 400 seeds. Some seed banks recommend 5% of the seeds stored is subjected to regeneration tests. In large seed banks, regeneration tests are done continuously, on the seeds of one species or the other.

Two types of seed storage are normally practiced in a seed bank. As per the first, base collections are stored under optimum conditions and are not interfered with until reduced viability is noticed through periodic germination tests. When reduced viability is observed, a new seed generation is carried out. In the second type of seed storage, active collection of seeds is lone, from which subsamples can be taken periodically for experimentation, exchange, evaluation and display. The active collection need not necessarily be stored under optimum seed storage conditions and can be multiplied periodically by growing a new generation plants and reharvesting.

The most important seed banks in the world are: The United State's National Seed Storage Laboratory (NSSL) (Fort Collins, Colorado, USA the Vavilov Institute. (Leningrad), the Izmir Centre (Turkey), the Royal Botanic Gardens (Kew) (seeds of 4000 species have already been banked and there is a current programme to bank the seeds of the entire British flora of some 1500 species, Prance 1997) and the Iberian Gene Bank (Madrid). In addition, nearly 580 botanic gardens of the world have developed facilities for seed banks of wild taxa, of which at least 150 have low temperature seed storage facilities. While some seed banks specialize in the storage of seeds of taxa in specific geographic areas others specialize in seeds of a particular taxonomic group. Some banks concentrate on seeds of forest trees, and some on specific crops As examples of the latter can be mentioned the 60 seed banks developed and promoted by IBPGR but even these, until very recently, have not a attempted to store seeds of wild relatives of crops The total number of accessions of PGRFA stored in seed banks worldwide is 3, 610, 428.

There are disadvantages in the seed bank technique as well. It cannot be practiced for all seeds. It is also criticized because it 'freezes evolution' of plants; seed germplasms held in banks are no longer continuously adapting to changes in the environment, such as exposure to new races of pests or climatic stresses/changes.

'Test-tube' Gene Banks

Many plants either do not produce seeds (i.e. clonal crops) or are not normally reproduced from seeds so as to maintain intact a highly heterozygous genotype. To these categories belong short-lived plants which are propagated from tubers, bulbs, corms, rhizomes, roots etc. as well as long-lived shrubs and trees, which are propagated vegetatively. These taxa are conserved through the maintenance of their vegetative propagules under appropriate conditions. Propagules of short-lived taxa have a storage life of only months rather than years. Potatoes can normally be kept at 4°C until the next spring or a further period of 12 months but not beyond. Most other roots and tubers have a storage life of less than 12 months. Cuttings of shrubs and trees, either unrooted or rooted, can be stored between -2 and +2°C up to a maximum of five years.

Pollen Banks

Pollen storage is very important, as it can make available directly the pollen required for crossing and breeding works, especially in breeding tree. Since it is now possible, at least in a few taxa to raise whole plants as haploids from pollen grains, pollen banks have assumed additional importance. The major disadvantage of a pollen bank is that only paternal material can be conserved and regenerated. Adequate techniques for the fairly long-term storage of pollen are not yet available. Cryopreservation is required for long-term storage of pollen (Towill 1985). If the moisture content of pollen is suitably reduced, according to the requirements of a particular species, pollen can be kept at cryogenic temperatures of -180 to 196^{0}Cfor periods ranging up to 642 years, but in the majority of species mostly well below one year. Although the exact reasons for the loss of pollen viability/fertility in a very short time under apparently good storage conditions are not known, it is believed that the moisture content of pollen plays a very critical role. Therefore, cryopreservation for long-term pollen storage is unlikely to be within reach for general application. Until the causes of pollen breakdown under storage are well understood. However, freeze and vacuum-drying have both been successfully applied to storing pollen of a number of taxa even up to 12 years, usually at a storage temperature of +5 to -18 °C.

Field Gene Banks

This is one of the major methods of *ex-situ* maintenance of taxa that must be conserved. A field gene bank is an area of land where collections of growing plants of species needing conservation are assembled;' the assemblage contains as many individuals of the target species as possible in order to sustain genetic diversity. These field gene banks make available plant material for breeding, reintroduction, research especially in population genetics, physiology, microbiology, biochemistry, nutrition and processing technology, and for several other purposes.

Field gene banks are particularly useful in the conservation of perennial species and therefore are of greatest importance in forestry. They have also been established in agriculture/ plantation sectors providing the required germplasms of such tropical crops, as cocoa, coconut, rubber, mango, cassava, coffee, banana, sweet potato and yam. The -IBPGR has initially, established/promoted^{-}23 field gene banks for crops. Several of these also contain germplasms of wild relatives of domesticated crops.

The characterization and documentation of germplasm resources in a field gene bank consist of five operational procedures (IBPGR 1991): (i) Establishing the origin of the plant material: This is called Passport data. Passport data includes accession data, if an accession has been received from a breeder, another institution etc., along with details on site of origin, ancestor or pedigree. It will also include collection data if the accession is directly derived from a field collection, along with a description of the collection site, (ii) Characterization: This includes recording all highly heritable and easily identifiable characters of the plant; especially from a fully mature plant. These characters, often called Descriptors, must be those that are expressed in all environments, (iii) Preliminary Evaluation: It includes details on plant development and recording of characters expressed by the growing plant, (iv) Further Evaluation: This includes recording all the reactions of plants to physical stresses and to .pathogens and predators, (v) Management data: This includes handling of the genetic resource, its distribution /exchange, regeneration and maintenance etc.

Over the years 'the global network of base collections' has swelled to about 50 institutions and these institutions have accepted IBPGR's invitation to participate actively in this network. Now, more than 100 species are being conserved in field gene banks throughout the world. The institutions include some of the International Centres of Agricultural Research (lARCs) and some, national centres. The total number of accessions of PGRFA conserved in field banks is 526,300(FAO 1996a).

The advantage of field gene banks is their provision of materials readily accessible for utilisation and evaluation. A major disadvantage is possible reduction in genetic diversity of the material," thereby increasing its susceptibility to pests and diseases. Furthermore, field gene banks involve large areas of land, which limits the genetic range of the material that can be held.

DNA Banks

A DNA bank may be defined as a 'gene library' in which samples of DNA extract are stored. This provides a new option for accession of plant germplasm (Adams *et al.* 1994; Peacock 1989). The DNA samples are of three kinds: (i) total genomic DNA, (ii) DNA libraries and (iii) individual cloned DNA fragments including RFLP probes, mini- and microsatellites etc. Samples of the first type are made with DNA isolated directly from plant tissues. The DNA library preparation requires another step-fragmenting the isolated DNA with a suitable restriction enzyme and packaging the diverse mixture of fragments into a suitable cloning vector. The purpose of a DNA library is to retain each fragment from the original DNA extract so that the whole genomic DNA is represented in the mixture. The third type of DNA samples individual cloned fragments—are fixed and genetically .pure since each vector molecule in the sample is host to the same DNA fragment.

Stored DNA samples ideally serve two contrasting purposes: (i) they are very convenient experimental materials that can be shipped immediately without quarantine problems and put to use immediately for further analysis and manipulation at the molecular level, and (ii) they are ideally suited to a 'time capsule' approach to conservation. In other words, they are frozen genetic resources and potentially the most stable form of preserved germplasm; they do not require \ recurrent regeneration to retain their future utility indefinitely.

Concomitantly, DNA banks are afflicted with almost all the problems faced by seed banks, but more acutely. Proper, reliable documentation and labeling of DNA samples are very crucial to their use. These and the dispatch, receipt and use of these samples require a high level of technical skill. Moreover establishing ownership and control of DNA samples is a complex 'delicate' problem. These factors limit the contribution DNA banks could make to the conservation of biodiversity Furthermore, the sophistication *'immobilisation'* techniques and the potential power of PCR amplification methodologies notwithstanding, total genomic DNA sample are virtually non-renewable. Thus DNA bank offer no newer solutions at least for the present, in the conservation of endangered species. DNA storage invariably only allows for recovery single genes but not of whole genomes (Peacock 1989). DNA Data Bank of Japan (Mishima, Japan). The main aim of such a network is to make biological resources more widely available for human benefite through increased research work and use: However; it should be understood that it is only an adjunct and not an alternative methodology in conservation. So a DNA bank cannot replace a field gene bank despite being less costly than the latter.

In addition to DNA banks, there are RNA and protein banks in some developed countries. The major protein databases are the PIR-International Protein Sequence Database (Multinational) and the SWISS-PROT Protein sequence database at Geneva. A Ribosomal Database exists at the University of Illinois, USA.

In vitro Conservation Methods

This-form of conservation is very important and is followed throughout the world by many, institutions: Most of the *in-vitro* methods have several advantages, such as greater safety from viral attack, lower cost and accommodation for tiger numbers (Withers 1989). All the methods involve storage of plant germplasms under *in-vitro* conditions. Meristem tips and buds are usually stored; such storage is especially followed for those taxa whose seeds are recalcalcitrant. Very often the meristems or buds ftp intact plants or the adventives 'embryos' produced directly from *in-vitro* grown explants or calli coated with materials such as alginate or neutral gums and stored. Such resultant structures are often called 'synseeds'. Very rarely calli are stored *in vitro.* Around 1500 wild taxa have been stored *in vitro* in various institutions around the world. The number of accession of PGRFA conserved *in' vitro* is estimated to be 37,600.

In-vitro storage is labour-intensive and costly since subculturing is necessary at regular intervals to test viability of the stored tissue. The annual average total cost for conservation for one accession is estimated to be $82.92 (see Virchpw T998). The other disadvantage is the risk of somaclonal variations that develop under *in-vitro conditions.*

Ecosystem Restoration

Ecosystem or Habitat restoration (more often treated under a separate discipline called 'Restoration Ecology') is a very rapidly growing and intellectually exciting aspect of conservation science." It refers to the task of 'fixing' damaged ecosystems. Thus, ecological restoration can be crudely but effectively defined as 'making nature' 0ackson 1992). The Society of Ecological Restoration (SER) defines it as 'the process of intentionally altering a site to establish a defined, indigenous, historical ecosystem'. The goal of this process is to emulate the structure, function, diversity and dynamics of the specified ecosystem (SER1991); The growing interest in this area-is already reflected in the founding of the SER in 1987 and more recently in the launching of its new journal *Restoration Ecology.* An important edited book entitled *Restoration of Endangered Species* (Bowles and Whelan 1996) has also been published.

Habitat restoration efforts have to be delicately balanced after due consideration of the economic and political demands of humanity on the one hand, and the biological requirements of the species/habitats targeted for restoration, on the other. This leads to the situation wherein conceptual issues important to habitat restoration range from the sociopolitical (including the management of restoration efforts), to the biological such as population biology, landscape ecology etc. (Bowles and Whelan 1996). Brown (1996) drew the attention of restorationists to the fact that they should not ignore the situation wherein society could suffer missed economic opportunities due to land being dedicated to restoration instead of to other direct uses. In many countries, restoration is attempted at several smaller sites for many reasons including financial, logistic, bureaucratic and biological.

Reintroduction is one type of restoration in which a species is intentionally introduced into its native habitat and range from which it disappeared or became extirpated for some reason or the other (Cairns 1986). Reintroduction is also called translocation (Given 1996; Templeton 1996). Reintroduction, as a rule, is done from materials of a taxon assembled and cultivated *ex-situ;* often the same sources are depended on for occasional replenishment. During Reintroduction care must be taken to see that the plant becomes firmly established in the original habitat and that a critical minimum viable population is established for proper reproduction.

Plant reintroduction is a high-risk and high-Cost strategy of ecological-restoration. (Maunder 1992). With both annuals and perennials, the success rate of reintroduction reaches the highest with materials derived from the transplant site and thus the microhabitat adaptation becomes a distinct advantage. In certain instances, however, reintroduction has involved the translocation of genotypes across geographic ranges, resulting in the introduction of 'incorrect' genotypes where they do not belong. Reintroduction demands expertise in management skills and enough resources for operations ranging from collection of plant materials, raising seedlings, choice and preparation of transplant sites, planting, protection and further safeguarding of transplant populations.

Reintroduction calls for knowledge and information about the taxon's key genetic, demographic and ecological traits that affect its vulnerability to stochastic extinction events. Inaddition, information on the causes of, or circumstances contributing to, the decline of the original population size is needed for any attempt to counter adverse ecological factors such as the presence of predators, parasites, competitors, nutritional imbalance or deficiencies, or the decline or absence of beneficial co-occurring taxa (such as pollinatots. and fruit/seed dispersers) or adequate water supply etc. (Lande 1988; Menges 1991). Details on the autecology of the target species are also very essential.

A recent survey indicated that about 250 projects in over 25 countries involving about 35 plant families have been undertaken thus far to f introduce species into their native habitats. However, very little has' been done in developing countries, including India, in the tropical belt. The most important reintroductions include *Stephanomeria malheurensis* (Asteraceae) jn" Oregon, USA from where it became extinct, *Pediocactus knowltonii* (Cactaceae), a highly endemic taxon in New Mexico, *Sophora fernandeziana* (Leguminosae) in the Chilean island of Juan Fernandez, *Ruizia cordaia*) highly endangered shrub in the Indian Ocean island of Reunion, *Gentiana nivalis* (Gentianaceae) in Scotland, and *Trochetiopsis melanoxylon* (Sterculiaceae) in the island of St. Helena.

Ecosystem restoration and species reintroduction are not, however, without problems. There is scope for making innumerable mistakes, even devastating ones that could lead to ultimate loss of the target species. In the'coming years, unfortunately, ecosystem restoration will be more difficult to execute since the rate of ecosystem/species loss is increasing at an alarming rate.

***In-situ or Ex-situ* Conservation**

It has repeatedly been argued both in favor and against *in-situ* and *ex-situ* conservation efforts. However, after a detailed and critical analysis of these arguments, one necessary concludes that the safest and perhaps also the most effective conservation strategy is that which combines these two complementary methods. *Ex-situ* conservation is to a large extent subsidiary and complementary to *in-situ* conservation. The latter has the potential for long-term preservation of ecosystems, species and populations under conditions of continuing adaptations. Tree species are preferably conserved *in-situ* since they require considerable space to conserve the required critical minimum viable population, "which varies from 500 to 5000 individual trees (Prance 1997). *In-situ* conservation also protects the associated animals and microbes (such as pollinators, dispersers, rhizobia and mycorrhizae), thereby enabling free energy flow.

The *in-situ* approach is essential in places whose flora has not been adequately inventoried. *Ex-situ* conservation affords the freedom to select a particular population, species or ecosystem for priority conservation on geographic or ecological grounds, for educational reasons, or because of the mere fact that the system in question is endangered/threatened in its natural environment. In fact Article'9of "the Convention on Biological Diversity states that *ex-situ* activities should be undertaken as far as possible and as appropriate, and predominantly for the purpose of complementing in-situ measures.

Ex-situ Conservation of Microbes

Both efforts and information with respect to *ex-*, *situ* conservation of microbes are lacking. However, a wide range of techniques are available for the preservation of microbial taxa and their strains. Of these, lyophilisation through freeze-drying and cryopreservation in liquid nitrogen are the most efficacious for long-term storage. It should be mentioned, however, that as yet not all micro-organisms are amenable to preservation by these methods.

Table 3.4: Microbial culture collections currently holding IDA status (from Sekar and Kandavel 2002)

S.No.	Country	Depository Institution
1.	Australia	Australian Government Analytical Laboratories (AGAL)
2.	Belgium	Belgian Co-ordinated Collections of Micro-organisms (BCCM™)
3.	Bulgaria	National Bank for Industrial Micro-organisms and Cell Cultures (NBIMCC)
4.	Canada	National Microbiology Laboratory, Health Canada (NMLHC)
5.	China	China Centre for Type Culture Collection (CCTCC) China General Microbiological Culture Collection Centre (CGMCC)
6.	Czech Republic	Czech Collection of Micro-organisms (CCM)
7.	Germany	Deutsche Sammlung von Mikooganismen and Zellkulturen GmbH (DSMZ)
8.	Spain	Coleccion Espanola de Cultivos Tipo (CECT).
9.	France	Collection nationafe de cultures de micro-organisnies (CNCM)
10.	United Kingdom	Culture Collection of Algae and Protozoa (CCAP) European Collection of Cell eultures.(ECACC) CABl Bioscience, UK Centre (IMI) National Collection of Type Cultures (NCTC) National Collection of Yeast Cultures (NCYC) National Collections of industrial, Food and Marine Bacteria (NCIMB)
11.	Hungary	National Collection of Agricultural and Industrial Micro-organisms (NCAIM)
12.	Italy	Advanced Biotechnology Centre (ABC)

		Collection of Industrial Yeasts (DBVPG)
13.	Japan	International Patent Organism Depository (IPOD)
14.	Republic of Korea	Korean Cell Line Research Foundation (KCLRF) Korean Collection for Type Cultures (KCTC) Korean Culture Centre of Micro-organisms (KCCM)
15.	Latvia	Microbial Strain Collection of Latviaj[MSCL)
16.	Netherlands	Centraalbureau voor Schimmelcultures (CBS)
17.	Russian Federation	National Research Centre of Antibiotics (NRCA) Russian Collection of Micro-organisms (VKM) Russian National Collection of Industrial Micro organisms (VKPM) GNIIGenetika
18.	Slovakia	Culture Collection of Yeasts (CCY)
19.	U S A	Agricultural Research Service Culture Collection (NRRL) American Type Culture Collection (ATCC) IAFB Collection of Industrial Micro-organisms
20.	Poland	Polish Collection of Micro-organisms (PCM)

In fact, because of this problem the world network of microbial collections contains only a tiny fraction of the microbial species present in the environment. For example, estimates place at least 36 major divisions in the domain Bacteria, but only four are even moderately well represented in culture collections. For many of these divisions not even one representative species is present in culture collections. It is therefore, suggested that for non-culturable taxa, DNA banks should be established (Fuerst and Hugenholtz 2000). The development of programmable coolers is enabling protocols to be devised for the cryopreservation of even those microbes previously considered recalcitrant.

Even where species cannot be grown in pure culture, host tissue containing these microbial species or samples of other substrates such as soil can be preserved by cryopreservation. The readers are advised to refer to the works of Kirsop and Doyle (1991) and the World Federation for Culture Collections, WFCC (1990) in which guidelines for the establishment and operation of such collections are provided. At present the World Data Centre for Micro-organisms (WDCM), established by WFCC and sponsored by UNEP, UNESCO and RIKEN holds a database on about 800,000 (786,328 to be exact) micro organism strains held by about 500 (482 to be exact) collections from about-60 Countries. These include fungi (45%), bacteria (43%), viruses (2%) and others (plasmids, plant cells, algae etc.).

Special mention must be made here of the Budapest Treaty and the Microbial Type Culture Collections (MTCCs). The Treaty came into force early in 1977 and was amended in late 1980. At present 44 states and three intergovernmental industrial property organizations are signatories of the Budapest Treaty. The signatories include India. As per this Treaty, certain organizations involved in microbial culture collections are recognized as 'International Depository Authorities' (IDAs). Anybody/any organization desirous of securing a patent involving a microorganism is mandatorily required to deposit the microbe-in any one of the IDAs mentioned in Table 3.4.

PLANTS Vs. PEOPLE

Loss as well as conservation of diversity is an issue of great social concern, since biodiversity has very great intrinsic value in a socio cultural system. However, the intimate relationship between society and biodiversity has not yet been fully realized by many people in this mechanized world. This is evident from the report (OTA 1987) which states. Social and political processes influencing hoi biological diversity is perceived and valued are the least well understood and, in the long run, the most important factors affecting success of onsite diversity maintenance'. In fact, sociologist’s anthropologists and historians have to develop very important descriptions of social factors affecting biodiversity maintenance at specific sites, although some effort has already been made towards this goal. It is also important to remember to educate people that science alone cannot protect biodiversity: Society-and social and cultural values must be called in as well in the conservation and protection of nature and its bio resources. This section highlights how society practised biodiversity conservation in the past by attaching ethical, aesthetic and religious values to it. The role of NGOs in persuading and pressurizing society to fight against attempts by the State to degrade and deplete bio resources on the pretext of developmental activities and welfare measures to people is also emphasized.

Sacred Groves

The present technocratic and scientifically oriented society mistakenly considers that religion is not interested in protecting and managing biodiversity. The truth, however, is that religious values very often help to protect biodiversity. The practice of protection of patches of forests with temples in their vicinity has long been in vogue in

India and a few other parts of the world. In some instances, forest patches or gardens with local floristic elements (often called *Nandavanas)* have been specially created near established temples and declared sacred to ensure their protection and conservation. Such sacred groves and gardens dedicated to the worship of the Presiding Deity of each temple are mentioned in ancient Greek, Latin American and Indian literary works as well as in epigraphical records and copper plates of these countries.

Data also come from folk traditions, history and traditional knowledge passed on through several generations. There are reports of sacred groves in the Near East, Europe, North and Sub-Saharan Africa, India, S.E. Asia, Oceania, China, Japan, Siberia and the - Americas (Hughes and Chandran 1998; Hughes and Swan 1986). There are several referencesto sacred groves in the Old Testament also touching plants (and animals associated with them) in these sacred groves and gardens was forbidden to all except the temple priest, and his too restricted to offerings to the Presiding temple Deity and curing the ailments of local people (the temple priest was invariably the village doctor). The groves-were considered the property of Gods, who may be male or female and represented in the temple as a slab of stone, hero stone, *'Sati* stone or trident. Since sanctity was ascribed to the plants of such groves and since spiritual beings were believed to reside in such places, ordinary human activities were voluntarily precluded. These activities includes tree-felling, gathering of wood/fuel and plans and leaves, hunting, fishing, grazing by domestic animals, ploughing, planting and harvesting and dwelling.

This ensured the conservation and preservation of the local vegetation for posterity. It should not be thought that such groves and gardens and the idea behind their establishment passed away with the ancient world. On the contrary, several sacred groves and temple gardens persist in many parts of India and a few other countries even today, in spite of fee fact the adjacent forests and vegetation have been total or partially lost. For example, *Ginkgo biloba,* the living fossil, is presently growing in one of the largest 'semi natural populations at Tian M Shan, near the KaShan Buddhist temple China (del Tredici *et al.* 1992).

In India, several thousands of sacred groves and temple gardens of various sizes (from clumps of trees to several hundred hectares) and diverse floristic composition have been reported in all vegetation types ranging from evergreen forests to desert/arid vegetation. About 42 sacred groves covering an area of 39,063 hectare are estimated to be distributed in India (Malhotra 1998). Groves are reported in areas from the highest mountain peaks to sea level (Kushalap and Bhagwat 2001). The largest sacred *grove* Mawflong, occurs in Meghalaya near Shillor Sacred groves are known by several names India depending on the place, *Kan* in Karnata and part of Maharashtra, *Kavus* in Kerala, *Deorai* in Madhya Pradesh, *Devarakadu* in northern Karnataka and Goa, *Orans* in Rajasthan, *Mawflong* in Assam and Meghalaya, *Koilkadu* in Tamil Nadu etc. Floristically such groves even today contain taxa lost/endangered in adjacent regions. Several endemics are today reported only from such groves, for example *Dipterocarpus indicus, Myristica fatua, Pinanga dicksonii, Manilkara hexandra* etc.

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Responsibility for protecting groves and enforcing rules were assumed by the local community since the grove was an integral part of the village society. Local autonomy was given to these groves, although epigraphical records indicate that the committee in charge of temples and associated groves included a representative of the state/king of that region. The priest of the temple was often the only person authorized to enter the grove and that too only for collecting flowers/fruits to offer to the presiding deity or herbals to cure diseases of the local people (Krishnamurthy 1999; Swamy 1973). Sacred groves, wherever still present, should be preserved and restored for several reasons, including their value as historical evidence for the relationship of human beings to nature.

Sthalavrikshas

Sthalavrik Shas is a Sanskrit word meaning temple trees. In India every temple, whether Hindu, Jain or Buddhist, had and still has a specific tree taxon cultivated very near to the *sanctum sanctorum*, the place where the Presiding Deity/Idol is erected. That particular tree is the temple tree for that temple. The idea behind this is that the people of the village where the temple is located should be very much concerned to protect trees in general and express their society's sentiment by selecting a representative local tree taxon as the temple tree. This is yet another form of people's regard for nature, nature worship and an expression of societal concern for the conservation of plants. Ancient Tamils, for example, thought that Gods resided in trees and by worshipping trees they worshipped God.

They further thought that different Gods resided in different types of trees and hence they planted the specific temple tree in temples meant for specific Gods. As many as 65 temple trees are recorded in Tamil Nadu alone, each in specific temples.

People's movements for Biodiversity conservation

People throughout the world are feeling uneasy about modern developmental schemes, which have resulted in the substantial loss of biodiversity, thereby denying them a just, equitable and sustainable resource base. Expression of such resentment has been spontaneous in many places and has resulted in resistance movements to retain control over national resource bases and to save them from 1organised ecocides. The concern of the local society in all such cases has been to prevent the total destruction of the renewable resources on which their lives and livelihood depend. Although there are several such resistance movements, only the most important are described here.

Chipko Movement

Chipko means 'to hug' or to embrace in affection. The chipko movement is a success story in environmental conservation and credit for it goes to the women of Reni village of the Alaknanda catchment area in the Uttarkhand region of the Himalayas of India, who sought to protect the local forests called *Myka* ('mother's house'). It was prompted by an order issued in the 1960s by the Government of India to cut trees in the Himalayan foothills on a large scale. This led to severe floods in 1970 which swept away 6 bridges, 16 footbridges and over 600 houses, in addition to destroying crops over hundreds of hectares, affecting no less than 100 villages in the area. The *Chipko Andolan* (Chipko revolution) was born when the women of the village sought to save the forests in this extremely sensitive region of the Alaknanda catchment by marching to them shouting slogans and hugging the trees when contractors were ready to cut them down. As a result of this pressure, the contractors had to abandon their operations (Bhat 1987).

The same story was repeated in 1975 when 200 women in Gopeshwar, ehamoli district, waged a war against the cutting of oak trees by the district administration. Women of Bhyundar village in the lower reaches of the famous Valley of Flowers also went on the warpath with their 'Chipko'. In 1980, women of Dungri-Paitoli villages in the Chamoli region of Uttarkhand also resorted to the Ghipko agitation to save their forests. The action was repeated in the 1980s in Bached village of Gopeshwar by 200 women, who prevented the felling of 1600 trees. The local women argued that even dead trees should not be removed, as the lumbering practices would invite soil erosion.

The mother organisation of the Chipko movement .was the Dasholi Gram Swarajya Mandal (DGSM) led by Mr.Chandi Prasad Bhat and Mr.Sunderlal Bahuguna. Chipko was only one of the *Andolans.* The DGSM educated the villages about the importance of forests and their conservation through lectures ecodevelopment camps, tree plantation programmes, construction of simple water distribution schemes, and setting up rnicrohydel projects with locally available technologies. The Chipko movement became the spearhead for communities elsewhere. In the state of Karnataka a similar people's movement was organised, the 'Appiko movement' to save forests.

Chico River Dam and Tribal Campaign

The Cordillera highlands of the northern Philippines witnessed a successful struggle for self-determination by the tribals of the area who traditionally tapped the forests for their livelihood.

The government planned construction of four dams along the Chico River two each in the Kalinga-Apayao and the Mountain Province. The Bontok and Kalinga tribals resisted this step as the project would displace an estimated 100,000 person's and submerge 2000 ha under rice cultivation and 2500 ha under coffee and fruit plantations. After a great struggle by the tribals and the Cordillerate People's Bedong Alliance (CBA), comprising 130 organisations, the Chico River dam project was shelved.

Participatory Forest Management

A young forest officer, Ajith Kumar Banerjee initiated PFM in Arabari, state of West Bengal India in 1972. It subsequently expanded to other states of India and became a very significant turning point in the history of forest conservation not only in India, but other Asian countries. The essential feature of PFM is that the State and Society become partners in the management of forest resources. The "State continues to own the resources but the benefits are shared, especially access to non-timber forest products for the community. This leads to the community developing an economic stake in the preservation of forests, which ensures its conservation and sustainable exploitation. Thus forests degradation can be reversed through PFM which has been observed in several forest tracts of Indi over the last 25 years.

Role of Universities and Other Educational Institutions in Biodiversity Conservation

Needless to say, biodiversity and its conservation have been largely conceived and guided by the academic community in universities and other institutions of learning (Temple 1995). Academic interest in the science of biodiversity and conservation is strongly motivated by the high level of scientific rigour, multi- and interdisciplinary approaches, and innovative measures requisite for tackling biodiversity problems, which only an academic community possesses. Governmental agencies and private groups interested in biodiversity may not have the expertise necessary for solving all the problems; their target is usually limited to specific categories of biodiversity for study and/or conservation. Although biodiversity science has emerged with contributions from useful theories and hypotheses (such as the Island Geography Theory), new theoretical contributions have been few in recent years. These can only be 'brainstormed' by academics in institutions of higher learning. Moreover, a complex web of problems remains untackled in the biodiversity crisis. This web likewise can only be untraveled by innovative, mission-oriented and crisis-driven academicians.

Another need of the hour is to improve the liaison between academicians, States, NGOs and other conservation practitioners. All the concerned parties should/must work together in resolving biodiversity issues. Further, academicians and academic institutions ought to play a major role in imparting biodiversity awareness through environmental education of the public that is both general and, where necessary, more specific. The general goals of environmental education (including biodiversity awareness) are quite simple: (i) Foster clear awareness of, and concern about, economic, social, political, and ecological interdependence in urban and rural areas, (ii) Provide every person with opportunities to acquire the knowledge, values, attitudes, commitments and skills needed to protect and improve the environment and its resources, (iii) Create new % patterns of behavior of individuals, groups and society as a whole towards the environment (International Environmental Education Program 1985). Education must be seen as a two-way process between environmental managers and professionals on the one hand, and society and people on the other.

Within this broad-brush approach to environmental education, facts about biodiversity and its conservation must be related to people's lives as well as to nature's needs. Often popular support for conservation of charismatic species or useful species is relatively high, but it is difficult to convince people of the importance of 'odd' taxa or unrealized genetic resources.

Biodiversity Awareness Programmes

The interrelated components of biodiversity education are awareness real life situations, conservation and sustainable development. An awareness programme is an essential precursor to formal learning. Rare plants or flagship species will generate interest; plants that appeal to people may create awareness. Awareness can also arise as a result of an environmental crisis. NGOs, environmental groups etc. can create awareness. Awareness programmes must be built upon and, where possible, consolidated by formal education. There is an enormous variation in background and fundamental perceptions of students, both within and between cultures. This suggests the need for a template approach (Pitt 1987) to education on biodiversity, in which different relevant examples are inserted into a basic text for wider use. The template approach allows the preparation of textbooks and supplementary resources with wide general application. Specific examples and emphasis can be inserted for particular regions or levels of education. This allows students to relate to those filings of biodiversity with which they are familiar.

The division of education into elementary, secondary and tertiary segments and into discrete subjects does not always fit well with the requirements of teaching biodiversity. The solution may be to recognize levels of complexity in education rather than formal, age-related grades. This would allow teachers to introduce aspects of biodiversity at appropriate levels of complexity (MacFie 1987). A balance between classroom based and outdoor (or real-life) teaching is essential and the latter can be achieved through visits to natural habitats. A botanic gardens and industries using plants.

At the tertiary level, biodiversity studies tend to be strongly oriented towards the subject *per se.* New careers in environmental education, ethics conservation, economics, law etc have come in. Information about Natural History Societies and biodiversity organisations and their activities could inspire students. Biodiversity clubs, formed in some countries, should be organised in all countries. Films, tapes, wildlife shows, flower shows, slide-tape programmes, video programmes or even Endangered Species Fairs can be arranged. In addition, tourism, posters, wall-charts, booklets, leaflets, low-cost books, trekking etc, may also help to propagate awareness. The Anglade Institute jointly runs by St. Joseph's College at Tiruchirappalli and Jesuit College at Kodaikanal in India is doing yeomen service in this context.

Biodiversity Education Resources

Some countries cannot afford to launch and maintain their own programme for biodiversity education. Help is available from international environmental agencies,: which fund the following aspects/programmes.

1. Educational aid to organise courses and to prepare study materials involving and relating to local people.
2. Workshops to train people in biodiversity awareness and education, who in turn train and educate others.
3. Preparation of educational materials in the local language for field biodiversity awareness programmes.
4. Courses on Reserve management, Sustainable utilisation, Herbarium & Museum management etc.

For instance, the International Environmental Education Programme (IEEP) handles all of the above. UNESCO and UNEP jointly founded IEEP. Among its achievements are the following: A series of international and regional meetings, regular free communication of information in five languages to more than 13,000 industries and institutions, including 900 Environmental Education (EE) institutions and 300 EE projects, undertaking of pilot and experimental EE projects, with involvement in over 13 countries of more than 260,000 pupils and 10,000 teachers, educators and administrators. There is also an International Centre for Conservation Education in England, which provides a global-focus for practical conservation education activities in developing countries.

Media

Media can play an outstanding role in biodiversity education and conservation (Bellamy 1979). Books, journals, newspapers, bulletins, radio and television form the important media for creating biodiversity awareness. Three separate television channels—National Geographic, Animal Planet and Discovery— are doing great service towards this goal. David Bellamy's 'Botanic Man' serials and programme in Thames television have already popularized plant science and conservation throughout the western countries. There are also special magazines such as *Pied Crow, Outreach* (supported by WWF/IUCN), *Down to Earth,* The Hindu Supplements on Environment etc. for this purpose.

Sustainable Development

Even today, the term 'sustainable development' remains enigmatic. Moreover, it continues to be treated, regrettably, more as a socio-economic and political concept, than a scientific or technological one. What is sustainable in a socioeconomic perspective may not really be so in an ecological sense and vice versa. What is sustainable in one place or at one time may not be so in another place or at another time, i.e., temporal and spatial constraints play a role. The net result is 'that the concept of sustainable development" is becoming increasingly 'complex and amorphous'. Today the number of definitions of sustainable development is thought to exceed l00 (Khoshoo 1998). Defining sustainable development in exact terms acceptable to all has proven very difficult.

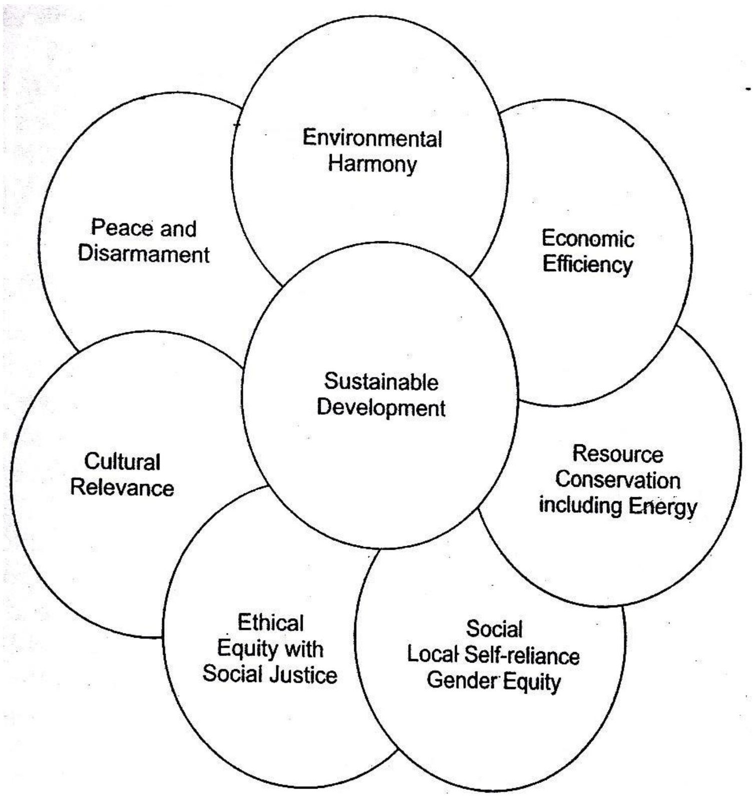

Figure 3.58: Major dimensions of sustainable Development.

Sustainable development became an issue on the environmental agenda in the second half of the 1980s, especially after the publication of the book *Our Common Future* by the World Commission on Environment" and Development (WCED). Now sustainable development has become a composite discipline including science technology, sociology, economics, ethics, trade, and politics, incorporating several dimensions (Fig. 3.58). Five years after the publication of this book and after the Rio summit in 1992 the term 'Sustainable Development' had become very popular throughout the world. Most people were made to believe, that sustainable development is a panacea for all the environmental ills and problems facing the earth, which led to considerable euphoria. A special UN Commission on Sustainable Development was formed, which had to report through ECOSOC to the General Assembly of UNO. In the last decade, consequently, an unusually large number of books and papers have appeared on this topic, with the gradual realization that sustainable development is not in actuality a panacea for all environmental ills.

Originally the WCED described sustainable development as development that ensures meeting 'the needs of the present without compromising the ability of future generations to meet their own needs' (WCED 1987). This implies that we should impose voluntary limits on the use of bio resources now for the benefits of our children and grandchildren, However, western countries have been rather indifferent to the concept of sustainable development, holding it would be 'a drag on their development'.

CHAPTER- III

GLOBAL PROGRAMMER OF CONSERVATION

INTRODUCTION

There is an ever-growing demand for bioresourees by humankind. It is fully realized now that these growing demands can no longer be met by tapping the still unexploited bioresourees or by trade-offs between goods and services (Ayensu *et el.* 1999). Any nation can increase food supply by converting forestlands to agriculture but in doing so it curtails the supply of goods and services rendered by forests which are of equal or greater importance. The projected climatic changes may also exacerbate the act of balancing supply and demand of bioresources. Sectorial approaches to management of bioresourees made sense when trade-offs among goods and services were modest or unimportant. They are not sufficient today 'when ecosystem management must meet conflicting goals and take into account the inter linkages among environmental probables'. Therefore, we are now forced to look for an integrated approach to biodiversity management (Ayensu *et al.* 1999).

It is worth noting that the governments of the world's various nations had already made an important, but unnoticed, commitment to nature (including biodiversity) conservation and management through the World Charter for Nature, adopted by the General Assembly of the United Nations-in 1982 (McNeely *et al.* 1990). This Charter recognizes that humanity is part of nature that every form of life is unique and warrants respect, and that continued benefits from nature depend upon the management and maintenance of essential ecological processes.

In other words, the goal of biodiversity management is to strike the optimal balance between biodiversity conservation, advancing human sustainable living' and benefit sharing. Successful management depends on two things: (i) The social, political, economic and cultural contexts within which management objectives are pursued should be properly understood by policy-makers and managers, and (ii) Proper "tools and methods should be selected to attain the aforesaid objectives. An integrated, predictive and adaptive approach to biodiversity management requires three basic types of information (i) reliable site-specific baseline-information on all aspects of biodiversity; (ii) knowledge on how the value generation (in terms of goods and services) in specific ecosystems will respond to changing environments and (iii) integrated regional models that incorporate the biophysical, economic and technological changes (Ayensu *et al.* 1999).

The scientific community must immediately take steps to mobilize all its knowledge in a manner that can increase awareness, provide information, capacity building at local, regional and national levels and informed policy changes that will better manage the Earth's biodiversity. Biodiversity management can be brought about effectively through committed organizations at the national and international levels (both governmental and non-governmental) which frame policies and methodologies for execution.

They also collect/collate vital data, store them distribute them to the needy. In addition, trilateral and national treatises, conventions and legal systems help in the effective management of biodiversity. Biodiversity information and knowledge are made available to anyone interested through well organised databases. In fact, Article 7 d of CBD points out the requirement to 'maintain and organise by any mechanism, data derived from identification and monitoring activities'. Similarly, Article 17 of *CBD* is concerned with information exchange. Nowadays biodiversity and bioinformatics have grown to be made for each other. Biodiversity management therefore requires skills in interdisciplinary areas such as Biology, Economics, Anthropology, Engineering, forestry, Agriculture, Oceanography, Sociology, Management Science, Geography, Geology, computerization etc. This chapter provides tails on Biodiversity management.

Organisations Associated with Biodiversity-Management

Two categories of organisations are necessary for efficient management of biodiversity. The first, already stated in the preceding paragraph, is primarily concerned with framing policies and methodologies for execution besides serving as sources of data. The second is involved in financing biodiversity-related projects, workshops and other activities. Some organisations, such as IUCN, UNESCO and UNEP, are involved in both activities.

IUCN

IUCN stands for International Union for Conservation of Nature and Natural Resources. It is a federative membership organisation, composed essentially of governments or governmental agencies, and scientific, professional and conservation organisations. Its foundation was laid in 1948 at the International Conference held at Fontaineblen, sponsored jointly by UNESCO and the Government of France. The present name IUCN was given to this organisation in 1956. IUCN is also now designated as the World Conservation Union.

IUCN initiates and promotes scientifically based conservation measures in co-operation with the UN and other intergovernmental agencies, and with its sister organisation, the WWF (Worldwide Fund for Nature and Natural Resources). It functions and operates through several commissions and committees. The standing Commissions of IUCN include those on Ecology, National Parks and Protected areas, and Environmental policy. IUCN, through its Commission on National Parks and Protected Areas, has developed a system of classification of different types of protected areas, based on several management objectives. This system has 10 different types of protected areas, of which the World Heritage Sites and Biosphere Reserves have international standing and recognition. IUCN'S Commission on Environmental Policy is largely responsible for initiating negotiations way back in 1978, when the initial drafts for the Biodiversity Convention were prepared; in 1988 the IUCN circulated a comprehensive draft among the participating countries at the UNEP Governing Council. This was followed by the Rio Convention. IUCN'S Species Survival Commission (SSC), established in the mid- 1960s, has now approximately 3500 members in 135 countries. It aims at promoting action to arrest biodiversity loss and to restore threatened species to safe population levels. The SSC is divided into 95 Specialist Groups, which cover different taxonomic groups, geographic areas or subject areas.

IUCN has published among others, the following documents/books: (i)*World Conservation Strategy* (1980) in collaboration with WWF and UNEP, (ii) *Caring for the Earth—A Strategy for Sustainable Living* (1989) in collaboration with WWF and UNEP and (iii) Red Data Books (RDBs). RDBs are prepared by SSC in collaboration with WCMC. The first RDB on plants, published by Dr. Ronald Melville in 1970, was updated in 1973 as the IUCN Plant RDB. RDBs provide information on the current status and conservation requirements of the threatened plant species of the world. For each threatened species details are provided on distribution, population status, habitat, ecology and potential conservation measures. Red Data volumes are divided on taxonomic or geographical bases.The most important books relating to plants are *IUCN Plant Red Data Book* by Lucas and Synge (1978), *The Plant Red Data Book of Rodrigues by* Strahm (1989), *Draft IUCN Red List Categoriesil993), IUCN Red List Categories.(EJCM.m5)* and *IUCN Red List of Threatened Species 2000* compiled by C. Hilton-Taylor, (iv) IUCN Bulletins, (v) IUCN's first edition of the *United Nations World List of National Parks and Equivalent Preserves* (IUCN 1992) and subsequent lists (IUCN I994a,b), (vi) *Global Biodiversity Strategy: Guidelines for Action to Save, Study, and Use Earth's Biotic Wealth Sustainably and Equitably* (WRI/IUCN/UNEP, Washington~DC-1992). IUCN convenes General Assembly meetings every third year. Its actions are reported in IUCN Bulletins. IUCN has also organised/supported several conferences /workshops on biodiversity. It has about 60 nations and 128 governmental agencies as members. Gland, in Switzerland, is the headquarters of IUCN.

UNEP

UNEP stands for United Nations Environment Programme. It is a UN agency engaged in the coordination of intergovernmental measures for monitoring and protecting the environment, achieving sustainable development and resolving biodiversity issues. It has the following threefold mandate: (i)-to create awareness on global environmental problems, (ii) to build consensus on actions addressed towards these problems and (iii) to promote and support such action programmes. UNEP was formed subsequent to the UN Human Environmental Conference at Stockholm in 1972, initially with an Executive Body (the Governing Council) of 50 members. A voluntary UNEP fund was established to finance the projects of the UNEP. For coordinating all activities of UNEP, an Environmental Co-ordination Board was created.

UNEP has taken up, among others, *the* following major activities (Olembo 1996): (i) biodiversity "country studies, (ii) global biodiversity assessment (GBA) projects and (iii) biodiversity data management (BDM) projects for capacity building in developing countries and improved in-country networking of biodiversity information. This effort is made to empower the countries to effectively manage their biodiversity data and information and to underpin the sustainable use of their genetic resources. The National Biodiversity Country Studies, Strategies and Action Plans were taken up to underpin and reinforce in-country biodiversity and assessment and planning processes, to identify national priorities for action, and to provide a baseline for monitoring effectiveness of national actions, policies and programmes on conservation and sustainable use of genetic resources. The UNEP Biodiversity Country Studies Projects, initiated in 1991, were funded by Global Environmental Facility (GEF). These are implemented in developing countries in cooperation with donor countries and UNDP. By about 1995, 19 studies had been completed and several more were in progress.

The GBA was commissioned and published after the CBD was signed. The Scientific and Technical Advisory Panel (STAP) of the GEF recommended the need for a very comprehensive review of current knowledge of biodiversity to the UNEP. It was to meet this challenge that UNEP commissioned the GBA in 1993 and publication readied in 1995 November during the second conference of the parties to the CBD. The GBA was written by thirteen teams of experts involving 300 authors from over 50 countries; in addition, several hundred scientists from more than 80 countries, covering different disciplines of biology, economics, sociology etc., peer reviewed different parts of the text. The assessment was divided into the following sections. Introduction; Characterization of biodiversity; Magnitude and distribution of biodiversity; Generation, maintenance and loss of biodiversity; Biodiversity and ecosystem functions—basic principles; Biodiversity and ecosystem functions biome analysis; inventorying and monitoring of biodiversity; The resource basis for biodiversity assessment; Data and information management and communication; Biotechnology; Human influences on biodiversity; Economic values of biodiversity; Measures for conservation of biodiversity and sustainable use of its components (Heywood 1997a; UNEP 1995).

For political reasons and the fact that the GBA was not commissioned by governments but by a UN agency, assessment of country-level diversity was deliberately omitted, as were policy recommendations. Information contained in this assessment can be used for a wide variety of purposes, including conservation planning, monitoring and sustainable use of biodiversity; it can also be used by governments for assessing the state of environment in territories under their purview (see details in UNEP 1995). UNEP operates the Earth Watch Programme and funds publication of the magazine

Earthscan. It has held/supported several conferences, workshops and meetings. Inlndia, it has been involved in a number of projects including the Tree Planting Programme and the Ganga Action Plan.

UNEP has produced several seminal publications/documents in addition to *Global Biodiversity Assessment* (published by Cambridge University Press, 1995) mentioned above. These have brought into focus the pertinent issues of biodiversity conservation and its sustainable use. Other important publications to date are: (i) *World Conservation Strategy,* (ii) *Global Murine Biological Diversity: A Strategy for Building Conservation into Decision Making.* Centre for Marine Conservation, in association with IUCN/ WWF/UNEP and The World Bank. E.A. Norse (ed:). Island Press, Washington DC (1993), (iii). *Caring for the Earth—A Strategy for Sustainable Living,* in association with IUCN/UNEP/WWF, Gland, Switzerland(1991).(iv)*The World Charter for Nature,* (v) *Global Biodiversity Strategy,* in association with WRI and IUCN, Washington DC (1992), which provides guidelines for action to save, study and use the Earth's biodiversity sustainably and equitably, (vi) Endangered Species of the World under the title *Blue Book,* (vii) *Global Biodiversity: Status of the Earth's Living. Resources,* WCMC, Chapman & Hall, London (1992). (viii) *The Global Biogeochemical Cycles,* (ix) *World's Lakes Inventory,* (x) *The Norway/ UNEP Expert Conference on Biodiversity, Proceedings.* O.T. Sandlund and P.J. Schei (eds.) Directorate for Nature Management/Norwegian Institute for Nature Research, Trondheim (1993). UNEP is headquartered in Nairobi, Kenya.

UNESCO

UNESCO stands for United Nations Educational, Scientific and Cultural Organisation. It was established in 1945 as a UN Agency. In 1948 it funded for the establishment of the IUCN. UNESCO has also assisted in the creation and operation of networks such as the MIRCENS (Microbial Research Centres). Biosphere Reserves and other protected areas, and marine research stations. MIRCENs are the outcome of a joint effort by UNESCO, UNEP and the International Cell Research Organisation. A worldwide network of microbial culture collections was established and by 1992 there were 16 such collections, which are now known as MIRCENs (Table 3.5). Activities of MIRCENs typically include collection, maintenance, testing and distribution of microbes, and training of personnel. Though each MIRCEN works on its mandatory priorities, they all work together in strengthening the network.

Table 3.5: MIRCENs recognized by UNESCO.

1. Ain Shams University, Faculty of Agriculture, Shobra-Khaima, Cairo, Arab Republic of Egypt.
2. Applied Research Division, Central American Research Institute for Industry (ICAITI), Ave, La Reforma 4-47 Zone10, Apdo Postal 1552, Guatemala.
3. Cell Culture and Nitrogen-Fixation Laboratory, Room 116, Building 011-A, Bare-West, Beltsville, Maryland 20705, USA
4. Centre National de Recherches Agronomics d'Institut Senegalais de Recherches Agricoles, B.P. 51, Bambay, Senegal.
5. Department of Bacteriology, Karolinska Institutet, Pack, S-10401 Stockholm, Sweden.
6. Departments of Soil Sciences and Botany, University of Nairobi, PO Box 30197, Nairobi, Kenya.
7. Fermentation Technology MIRCEN, ICME, University of Osaka Suita-shi 656, Osaka, Japan.
8. Fermentation, Food and Waste Recycling MIRCEN, Thailand Institute of Scientific and Technological Research, 196 Phahonyothin Road, Bangkok 9, Thailand.
9. Institute for Biotechnological Studies, Research and Development Centre, University of Kent, Canterbury CT27TD, UK.
10. IPAGRO, Postal 776,90000 Porto Alegra, Rio Grande do Sul, Brazil.
11. Marine Biotechnology MIRCEN, Department of Microbiology, University of Maryland, College Park Campus, Maryland 207742, USA.
12. Mycology MIRCEN, International Mycological Institute, Ferry Lane, Kew, Surrey TW9 3AF, UK.
13. NifTAL, Project, College of Tropical Agriculture and Human Resources, University of Hawaii, PO Box "0", Paia, Hawaii 96779, USA.
14. Planta Piloto de Procesos Industriales. Microbiologicos (PROIMI), Avenida Belgranoy Pasaje Caseros, 4000 S.M. de Tucuman, Argentina.
15. University of Waterloo, Ontario, Canada N2LK 3G1, and University of Guelph, Guelph, Ontario N1G 2W1, Canada.

16. World Data Centre on Collections of Microorganisms, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-01, Japan.

The International Man and Biosphere Programme (MAB) were initiated by UNESCO in the early 1960s, took its final shape in 1968, and were actually launched in 1971. One hundred and ten countries co-ordinate in the MAB. Several UNESCO-MAB documents have already been prepared, wherein the objectives of the network of Biosphere Reserves, the characteristics which the Reserve must display and the action plans of these Reserves are detailed. Subsequently several MAP networks were established. These include the EuroMAB, USMAB, MAB-CYTED (Ibero-American Programme), CBRN-MAB (Chinese network) and MAB-GEF (Central European network).

UNESCO has also identified World Heritage Sites and listed them. A World Heritage Fund was created and is being managed by UNESCO's World Heritage Committee; the annual budget this fund is 2 million US dollars. UNESCO, with, the help of IUCN, was instrumental in the preparation of the draft for the Rio summit and convention. It, along with the International Union of -Biological Sciences launched in 1991 the famous co-operative scientific programme on biodiversity called 'DIVERSITAS' for studying the origin maintenance, loss etc. of biodiversity. UNESCO in co-operation with .IUBS and SCOPE has published the following book: *From Genes to Ecosystems: A Research Agenda for Biodiversity.* O.T. Solbrig, 1991. The headquarters for UNESCO is in Paris.

WWF stands for Worldwide Fund for Nature and Natural Resources. It was established in 1961 and headquartered in Gland, Switzerland. WWF International has several affiliated national units. The Indian unit was established in 1969 at the time of the XII General Assembly of the IUCN, held in New Delhi. The WWF international is controlled by a Board of international Trustees, while the national units are managed by separate national teams. For example the Indian unit has a Board of 8 trustees, with its headquarters in Mumbai. It has a network of 18 State and Divisional Units. WWF has initiated several specific conservation programmes in more than 24 countries, with importance given to endangered fauna and flora. The logo of WWF is the panda, as designed by Gerald Watterson.

ICSU

ICSU stands for International Council of Scientific Unions. It represents 80 of the words scientific academies or research councils; 50 nations are involved through national presentation. Many of these nations are signatories to the Biodiversity convention. ICSU is composed of 20 scientific unions including eight in biology, which have direct interest in biodiversity. These eight unions are: International Unions of (i) Biological Science (IUBS), (ii) Biochemistry and Molecular Biology (IUBMB), (iii) Pure and Applied Biophysics (IUPAB), (iv) Immunology Societies (IUIS), (V) Microbiological Societies (IUMS), (vi) National sciences (IUNS), (vii) Pharmacology (IUPHAR) and (viii) Physiological Sciences (IUPS).

The ICSU also supports 19 bodies that are interdisciplinary. Many of these are concerned i biodiversity. These include SCOPE (Scientific Committee on Problems of the Environment), IGBP (International Geosphere-Biosphere Programme), SCOR (Scientific Committee on Oceanic Research), COGENE (Committee on Genetic Experimentation) and CASAFA (Committee on Application of Science to Agriculture, Forestry and Aquaculture). The most important programme with explicit responsibilities in biodiversity undertaken by ICSU is DIVERSITAS jointly managed by IUBS, SCOPE and UNESCO.

The DIVERSITAS programme was launched in 1991. Its purpose is to combine activities in research inventory work and surveillance with training and awareness-raising. It is required by ICSU as one of its most important action programmes in environmental matters and has already obtained backing from numerous National Committees. DIVERSITAS has four main themes, which include inventorying and monitoring of overall biodiversity spatially and temporally and the study of genetic diversity for the conservation of wild relatives of cultivated plants. DIVERSITAS covers all levels of biodiversity, from genes to ecosystems, incorporating both marine and terrestrial environments. Special attention is shown to the ^rather neglected aspects of microbial biodiversity and aquatic biodiversity. It should be emphasised that DIVERSITAS appreciates the revival of taxonomy as the most relevant area and currently gives it the greatest priority. This programme also strives to remove the current dichotomy between the biodiversity agenda and priorities of developed and developing nations. DIVERSITAS promotes the use of UNESCO'S MAB network as the focal sites for inventory programmes. Several countries such as Brazil, China, France, Japan and the USA have started their own DIVERSITAS activities, but co-ordination between these has not yet been effected.

BioNET-International was initiated by the intergovernmental CAB-International in 1993 with the idea of helping to generate biosystematic self-reliance in the developing countries 0ones and Cook 1993) through the mobilisation and pooling of already existing biosystematic resources as well as through the transfer of skills, knowledge, scientific expertise and other resources provided by expert institutions of developed countries. BioNET has planned a series of interlinked, subregional Technical Co-operation Networks in developing countries, known as 'Locally Organised and Operated Partnerships' or LOOPs, supported by BIOCON and a central technical secretariat. Initially BioNET had a particular interest in microrganisms and some animal groups but subsequently included other groups depending on local needs. Four priorities have been identified for the initial activity of LOOPs: Information and communication services, personnel training, rehabilitation of collections, and development and application of new resources. LOOPs have been organised in Europe (EuroLOOP) (includes 60 institutions from 22 countries) and the Caribbeans (CARINET). Four other LOOPs in East Africa (EAFRINET), Southeast Asia (ASEANET), South Pacific (PACINET) and South Africa (SAFRINET) contemplated earlier (Jones and Cook 1993) "have now been realised.

FAO

FAO stands for the Food and Agriculture Organisation. It is a specialised agency of UNO established as early as 1945. FAO has several member nations. Although initially formed to take care of food and agriculture, FAO is now the chief organisation for protection and conservation of germplasms of all food plants and animals. FAO has its head office in Rome, Italy.

FAO programmes traditionally support developmental efforts in fisheries, forestry and agriculture. FAO's Global System for Conservation of Plant Genetic Resources was set up in 1983 to co-ordinate activities related to genetic resources concerning food and agricultural production (Glowka *et al.* 1994). It included two major developments: (i) The International Undertaking on Plant Genetic Resources, which aims to ensure exploration collection, conservation, evaluation and utilisation of plant genetic resources of present and future importance, (ii) The Commission on Plant Genetic Resources (CPGR), an international forum of more than 125 countries which promotes and implements activities of international undertaking. Later FAO policies and actions tended to have a larger impact on biodiversity. For example, after recognizing the rapid loss and degradation of biodiversity throughout the world, in 1989 FAO added Biotechnology and the Tropical Forestry Action Plan (TFAP) as priority areas. Numerous activities subsequently undertaken or co-ordinated by FAO are designed to mitigate biodiversity loss, especially in tropical forests.

TFAP is a programme of FAO intended to halt the destruction of tropical forests and to promote their sustainable development. The programme was initiated in 1985 and focuses on five issues: fuel wood and agro forestry, land use and watersheds, forestry management for industrial uses, tropical forest ecosystem conservation, and-strengthening institutions for research, training and education. Initially development of national level TFAP for every country with tropical forests (about 70 countries) was required and the FAO carries out all action plans mentioned above through national TFAPs.

FAO has assisted the UNESCO in the Man and Biosphere Programme and has co-operated with IUCN in the 'Caring for the Earth' strategy. Together with UNDP and the World Bank, FAO sponsors the Consultative Group on International Agricultural Research (CGIAR), which supports more than 6 International Agricultural Research Centres (IARCs).

The idea of establishing Genetic Resources Centres (GRCs) emerged from the very vast and still unparalleled collections assembled by N.I. Vavilov, his colleagues and the USSR Institute of Plant Industry. In the decade 1920 to 1930, this institute became a highly developed and successful GRC. The GRC idea was further molded at a conference convened by FAO in 1961 (whyte and Julen 1963) and subsequently another conference organised by FAO and international Biological Programme (IBP) in 1967 (Frankel and Bennett 1970). Interestingly, the term 'Genetic Resource' was first introduced in the latter conference. The decade 1965 to 1974, saw the emergence of what has been called the genetic resources movement', the initiatives for which came largely from the FAO panel of experts. The Consultative Group on International agricultural Research (CGIAR) was founded in l971 jointly by the World Bank, FAO and UNDP. FAO experts also played a prominent, role in a meeting convened at Beltsville, USA in 1972 by FAO and the CGIAR, which made recommendations for a global network of GRCs and for their co-ordination. These efforts ultimately led to the establishment of 16 IARCs as well as 227 seed banks from 1971 onwards; these IARCs consist of a consortium of donor countries and Foundation and Developmental Banks sponsored by the World Bank, UNDP and FAO. At present there are more than 16 IARCs, most of which are specifically responsible for germplasm conservation of specific crops and actively collect toe requisite material on a worldwide basis. For example, the IRRI (International Rice Research Institute) based in Manila, Philippines is concerned with the collection and maintenance solely of rice germplasm (both cultivated and wild) from every place throughout the world in which this plant is known.

Another organisation was established under IARC in 1974, namely IBPGR (International Bureau of Plant Genetic Resources), now known as the International Plant Genetic Resources Centre (IPGRI). Its head office is in Rome, Italy with affiliated NBPGRs (National Bureau of Plant Genetic Resources) in several countries. The IPGRI plays a major role in the collection, documentation and conservation of 'useful plants' and their wild relatives. It has developed a standardized description on a crop-by crop basis by printing gene bank catalogues and directories of germplasm collectors, and by holding germplasms of crop material. It also advises and encourages repositories of plant material to use standard passport data, to systematize holdings and to discard redundant or 'junk'- samples, i.e., poorly documented ones.. With the assistance of IPGRI, 90% or more of the known land races of crop taxa and over 510,000 accessions are now held by IARCs and seed banks.

CAB International

CAB International is an intergovernmental organisation. It provides very important research data together with scientific and developmental services for agriculture, forestry and related fields throughout the world. It also houses the world's largest bibliographic database in the form of CAB abstracts on research and scientific development. CAB International comprises four constituent International Institutions Entomology, Mycology, Biological Control and Parasitology.

WCMC

These initials stand for the World Conservation Monitoring Centre. It was founded in 1988. It is a joint undertaking of the IUCN, UNEP and WWF. It serves as a primary source of information on the conservation status of many species of plants (and animals) and monitors conservation and sustainable development. It maintains a database of published literature, unpublished reports, government reports, and references to conservation organizations, contacts and correspondents throughout the world. The detailed biological information available with WCMC covers the distribution, ecology and status of 52,000 plant species; data include population size, potential or actual threats and occurrence in cultivation. Also listed are key sites of high biodiversity and the locations and importance of about 16,000 protected areas worldwide. Mapped digitized data are also available.

ISBI

Driven by concerns of human effect on bioresources and with a view to integrating ecological sciences with resource management and development, the Ecological Society of America proposed the Sustainable Biosphere Initiative (SBI) with a list of ecological agenda. These agenda were further expanded in a workshop in Mexico in which leading ecologists from the world over recommended the establishment of a co-operative programme as a global venture, the International Sustainable Biosphere Initiative (ISBI). The central goal of the initiative is to 'facilitate the acquisition, dissemination, and utilisation of ecological knowledge to ensure the sustainability of the biosphere' (Ramakrishnan 1992).

The concept, of sustainability implies the current use of ecological systems with compromising the needs or options of future generations, which obviously involves trade-offs. One of the fundamental objectives of the ISBI is to achieve a better understanding of these tradeoffs. Highly interactive participatory research/ activity is visualised wherein ecologists join hands with planners and administrators, resource managers, specialists in several disciplines and society at large (Fig. 3.58). Three important components are visualised by ISBI for research priority: (i) diversity and sustainability, (ii) sustainability in changing biosphere and (iii) human dimensions of sustainability (Fig. 3.59).

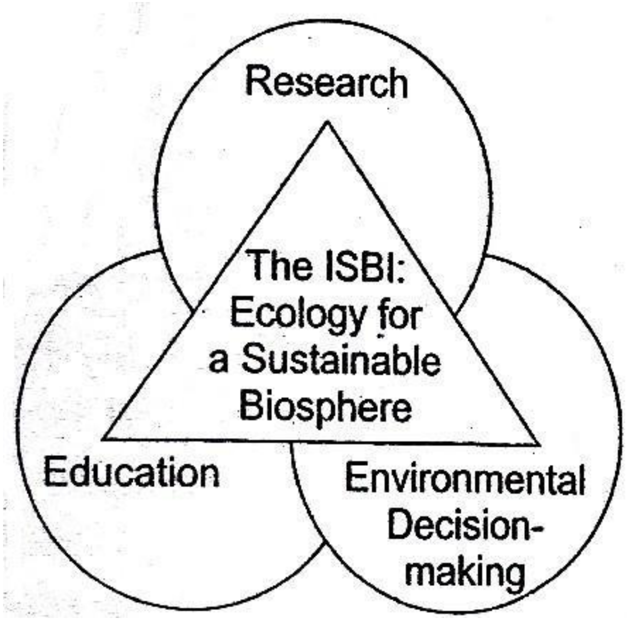

Figure 3.59: Research priorities in three facets of sustainability identified by ISBI.

Organisations Involved in Financing Biodiversity Management

It is often said, 'Conservation without financial resources is just conversation.' Allocation of adequate finance is essential for proper and effective conservation. There should be a suitable match between conservation needs and financial allocation at all levels. This section deals with organisations/ institutions involved in funding biodiversity initiatives.

GEF

GEF stands for Global Environmental Facility. At the annual IMF-World Bank Development Committee meeting of 1989, France suggested the creation of environmental protection activities that would provide benefits to the global human community. By November 1990 an agreement was reached between 25 countries on this suggestion and GEF was created. It was decided that the World Bank. UNDP and UNEP would co-operate in administering the GEF. GEF was required to develop a mechanism for not only establishing a new multilateral fund but also for distributing concessionary finance on loan or grant for the purpose of protecting the 'global commons'. By March 1991, 21 countries had committed approximately US $1-4 billion to the GEF fund over a three-year pilot stage. GEF would accept proposals for funding in four areas: (i) protecting the ozone layer, (ii) limiting greenhouse gas emission, (iii) protecting biodiversity and (iv) protecting international waters.

The main mandate of GEF with reference to biodiversity is to preserve specific areas of the world which contribute Goods and Services to humankind, such as harvestable materials for medicines or industrial products, genetic resources for food products and the regulation of climate and rainfall patterns. The GNP of the nation receiving grants from GEF should be less than US $4000 and the nation should also have UNDP programmes.

The GEF provided US $300 million for biodiversity during 1991- 1994 (McNeely 1996). The most important biodiversity projects funded by the GEF during that period include: Congo Tropical Forest Preservation, Bwindi Forest 2 Conservation in Uganda, Trust Fund for Environment Conservation of Bhutan Wildlife, Protected Areas Management in Laos, Wetland H Protection in Elkala National Park of Algeria, Forest Biodiversity of Poland and Conservation of Biodiversity in 20 protected areas of Mexico. In addition, GEF-funded a number of technical assistance projects in East Africa, Vietnam, South Pacific, Choco regions of Colombia, Guyana and the Amazon. The World Bank manages the GEF. After 1994 the GEF financed several programmes S on biodiversity in various parts of the world.

WHF

WHF stands for World Heritage Fund. This is one of the best known International Trust Funds for Biodiversity-related activities. WHF was established pursuant to the World Heritage Convention (WHC) in 1972. WHF raises funds by a combination of voluntary and compulsory contributions from contracting parties to the tune of 1% of their contributions to the regular budget of UNESCO every two years. The WHF committee is composed of 21 members elected by the contracting parties (117 parties as of 1993). Funding is given by WHF to protect cultural landscapes and World Heritage Sites (WHS) established by UNESCO. The annual budget of WHF is around US $2 million. Assistance is given for studies, provision of experts, training, supply of equipment etc., but assistance covers only part of the budget and the states are expected to contribute a substantial share for the project or programme.

Biodiversity Legislation and Conventions

Introduction

Primitive man, even from the hunter-gatherer stage, was highly dependent on the various elements of biodiversity; he had developed a unwritten code for the sustainable use of biodiversity. Such codes exist even today in several tribal pockets throughout the world. During the evolution of human society a civilisation, these unwritten codes were replaced by legislation. Only a few decades ago, however environmental law emerged as a distinct branch of law in order to regulate the activities of man towards the biotic and abiotic components of the environment.

Effective legal protection for biodiversity can be provided only after a synthesis of society structure, policy and regulation has been effected. Society must first realise that the fuel f or this process is an understanding of the biology community and our place in this community; we must realise that we are only fellow members the Earth's biotic community. Biodiversity law differs from other laws in that they, instead governing relationships between persons between persons and society, strive to protect biodiversity, the destruction of which affects of humanity. However, the implementation and enforcement problems of these laws are almost insurmountable. In several countries, a large number of environmental laws and treatises are really 'paper tigers' because governments last the will or ability to enforce them. The most noteworthy example is the lack of enforcement a legal ban on clearing tropical forests. In other words, there is no use of legislating biodiversity protection until our society is 'structured to man adherence to such protections possible'.

Throughout the world, biodiversity laws started as specialised sub-branches of agriculture and/or forestry laws; initially they dealt specifically with regulation of the exploitation, of wild species and the establishment of protected areas. Only slowly did they evolve as specialised biodiversity laws extended into laws pertaining to planning and land-use legislation. From the initial regulatory and punitive status, biodiversity laws are now increasingly developing to provide a framework for the establishment of procedures, and Institutions destined to facilitate and encourage biodiversity conservation and management programmes, to make biodiversity into a. public service and to promote better public awareness of biodiversity (Given 1996).

International Biodiversity Laws

International laws have two dimensions: public and private. With reference to the first dimension, international laws govern the activities and relationships between nations, although the principle of State sovereignty dominates them. Consequently, nations are no strictly bound by such international laws; their consent is very essential while approving or enacting such laws. Consent is often obtained through the signing of a treaty relating to these laws by duly empowered persons: officiated by the concerned country and the treaty subsequently ratified by an act of parliament or equivalent body of that particular country. With reference to the private dimension, it can be mentioned that private law operates within the context of the public law, and controls the activities and relationships of individuals and non-governmental organisations.

It is evident from the foregoing that treaties have become the backbone of international laws. Treaties are contracts providing for benefits to both the contracting nations and, therefore, if one - nation fails to comply with its treaty commitments; the other can retaliate by refusing to discharge its own obligations. Very recent developments in International Laws have resulted in treaties laying down general rules that the contracting nations should absolutely commit themselves to, failing which they self defeat themselves. But although binding upon the contracting countries, these treaties are very difficult to enforce (de Klemm 1990). This inherent drawback can be nullified to some extent, however, through the establishment of appropriate institutions, such as Conferences of the Nations and Secretariat. These would continually review implementation of the contents of the treaties, encourage and promote co-operation between the nations, and provide a forum wherein cases of non-compliance are discussed and solutions reached.

Table 3.6: Most important International and Regional Conventions on Biodiversity.

Sl. No.	Convetion	Year	Place	Importance
1.	International plant protection convention	1951	Rome	Global
2.	Convention on the High Seas	1958	Geneva	Global
3.	International convention for protection of new varieties of plants (UPOV)	1983	Geneva	Global
4.	Convention on wetlands of international importance, especially as waterfowl habitats (also called the Ramsaf convention)	1971	Iran	Global
5.	UNESCO convention for protection of the world's cultural and natural heritage	1972	Paris	Global
6.	Convention on international trade in endangered species (of wild fauna and flora) (CITES)	1973	Washingt on DC.	Global/Regi onal
7.	International Tropical Timber Agreement (ITTA)	1983	Geneva	Global
8.	Convention on nature protection and wildlife preservation in the Western Hemisphere	1940	Washingt on	Reginal
9.	African convention on conservation of nature and natural resources	1968	Algiers	Regional
10.	Convention on conservation of European wildlife and -natural habitats	1979	Berne	Regional
11.	ASEAN agreement on conservation of nature and natural resources	1985	Kuala Lumpur	Regional
12.	Protocol concerning protected areas and wildlife fauna and flora in the eastern African regions	1985	Nairobi	Regional
13.	Protocol concerning specially protected areas and wildlife in the wider Caribbean region	1990	Kingston	Regional

Other suitable steps towards implementation of the treaties without problems are: (i) underscore the obligation of contracting nations to provide periodic reports on the actions taken by each nation in implementing the contents of the treaties; (ii) empower the Conference or Secretariat to adopt specific recommendations relating to the treaty and (iii) allow admission of non-governmental organisations as observers at meetings of the Conference (Lyster 1985). The sources of International laws can be four. (i) international conventions, (ii) international custom (these first two as a result of treaties mentionSed above), (iii) general principles-of law and (iv) judiciary decisions and teachings of the most highly qualified publicists such as the International Court of Justice Statute 1948 (UNEP 1995). The most important international conventions/treaties are mentioned in Table 3.6.

Convention on Biological Diversity

Also called the Rio or Earth Summit, the Convention on Biological Diversity (CBD) is a major landmark in biodiversity management, regulation and utilisation. This convention was the result of very intense political interest in biodiversity and several years of intense biodiplomacy. Preparations for CBD were initiated by UNEP in 1987 with the formation of an Ad hoc Working Group of Experts. This Group of Experts met in 1988, followed by a meeting in 1991 of the Intergovernmental Negotiating Committee for a CBD. The agreed text for CBD was adopted by 101 countries in Nairobi in May 1992. The CBD was launched in June 1992, along with establishment of the Global Environmental Facility (GEF). The Convention came into force on 29th December 1993. This was followed by the first meeting of the contracting countries in the Bahamas in Nov-Dec. 1994. By February 1995/168 countries had signed this Convention, while by April 1995,188 countries had ratified its tenets.

The CBD was aimed at reaching a consensus among all contracting countries since there was (and still is) acute dissention between countries over biodiversity utilisation and conservation. Developed countries felt (and many still feel) that conservation of biodiversity, wherever it may be located in the world, is a common concern of humankind, while developing countries tended to show a strong 'country driven approach' with reference to the use of biodiversity for their overall economic development (Khoshoo 1996).

The preamble to the CBD states that the contracting parties (the Nations) are aware of the general lack of information and knowledge regarding biodiversity and of the urgent need to develop scientific, technical and institutional capacities to provide the basic understanding requisite for planning and implementing appropriate measures. The CBD has agreed to the proposal of 42 Articles and two Annexures.

Article 1 describes the objectives as follows: 'to conserve the maximum possible biological diversity for the benefit of present and future generations-and for its intrinsic value'. Article 3 emphasises the fundamental principle that the conservation of biodiversity is a common concern for all people and that the States should have the responsibility to ensure that their bioresources are developed in a sustainable way. Articles 7 and 8 emphasise *in-situ* and *ex-situ* conservation; they further emphasise that countries benefiting the most from biodiversity exploitation should also contribute the most to its conservation. Articles 14-17 deal with access to genetic resources and transfer of technology. A conference of parries to the CBD is held periodically. Since their first meeting, the parties have met four more times, the latest in Nairobi (15-26 May 2000).

Trade-Related Intellectual Property Rights

The other international treatises relating to biodiversity are the International Copyright Act of 1886 and the Berne Convention of 1875 (consolidated through several later treatises and Acts). The first provides nations with legal mechanisms for protecting, under their own laws, each other's copyrighted works and materials. The Berne Convention for the protection of literary and artistic works provides legal protection and control of biodiversity information. The World Intellectual Property Organisation (WIPO) is responsible for administering the Berne Convention and other agreements regarding Intellectual Property Rights (JPRs). TRIPs refers to Trade-related Intellectual Property rights and is a term used to describe that branch of law which protects the use of thoughts, ideas and information of commercial value.

As already stated, the law of IPR is meant to protect the legitimate rights of those who produce original work arid serves as an incentive. The primary formal mechanisms within the purview of this law are Copyright, Patent, and Trademark besides protection of undisclosed information, industrial designs, geographical indications, layout designs of integrated circuits, and anticompetitive practices in contractual licences (OECD1996; Sekar and Kandavel 2002). IPR is granted for a stipulated period (usually 20 years) and when this period expires, the patented information is available in public domain. Copyright work should be original and should be the result of a creative process, although national laws differ slightly in the strict enforcement and interpretation of the copyright provisions. This creates problems, especially for biodiversity databases. Patents are traditionally used to protect property rights related to devices or machines. However, at present patents are given it to software, specific information, ideas and even to biological organisms. The breaking down of distinction between software and information has blurred the strict adherence to patent and copyright provisions originally contemplated. Wide-area networks have thus increased the 'fluidity and accessibility of data by orders of magnitude’ (UNEP' 1995).

Application and enforcement of copyright and patent principles have been increasingly challenged in view of the aforesaid problems. The public in many countries of the world is increasingly seeking freedom of access to information and public databases. How much of such information is accessible and how many are subject to privacy is a teething problem in many countries.

TRIPs agreement came into effect on 1st January 1995 (see Website hrtp:// www.wto.org/wto/intellec/intellec.htm for the text of TRIPs). It also paved the way for the World Trade Organisation (WTO). Between 1996 and at the latest in 2005 all WTO member countries must apply the provisions of TRIPs agreement. Countries which do not yet meet the TRIPs standards have been given a period of five years to change their laws; this: period is extendable for another five years for the least developed countries. India, as a member of WTO, is obliged to change her patent laws latest by 31st December 2004 to bring them in line with the requirements of TRIPs. Approximately 70 developing countries have signed the TRIPs agreement. To date TRIPs is the most comprehensive multilateral agreement on Intellectual Property Rights (IPR). Since India is a signatory to the General Agreement on Trade and Tariffs (GATT) and a member of WTO, it is obliged to meet all the articles of TRIPs.

TRIPs also outline features on minimum standards, procedures and remedies for enforcement, and dispute settlement. It may be noted that each country has the option to frame its patent laws within the broad framework defined in the WTO agreement. In this era of biological sciences, resources of biodiversity are increasingly used both in conventional and in modern ways, the latter often through biotechnological methods. Biotechnology uses living organisms or their parts to extract, make or modify products of great commercial value, and also to develop individual cells of higher organisms and of microbes for specific uses. IPR for biotechnology is presently 'in a state of flux'. Two main systems of TPR currently obtain for biotechnology: rights in plant varieties and patents, both of which provide exclusive and time-limited rights of exploitation.

CITES

CITES stands for Convention on International Trade in Endangered Species of Wild Fauna and Flora. CITES, known in its early days as the 'Washington Convention', was the result of extensive lobbying by IUCN for international trade controls in .species that are, prioritised for conservation. The necessity for controlling international trade in endangered species, although recognised as early as 1911, and provisions to that effect incorporated in several international conventions on the conservation of wildlife, could not be realised in practice for a long time (Lyster 1985) not until CITES came into force (Favrel989). CITES was first arranged in 1973 in Washington DC. The trade agreements reached inthis convention weje enforced in 1975. By about 1994, the number of countries which agreed to enforce the recommendations of CITES, had increased from an initial 10 to 125. By 2000, the number of signatories had reached 140. This list includes India.

CITES is a major global biodiversity protection statute and is intended to be followed internationally. Its goal is 'to regulate the complex wildlife trade by controlling species-specific trade levels on the basis of biological criteria' (Trexler and Kosloff 1991). It includes all species 'threatened with extinction, which are or may be affected by trade'. Thus, CITES focuses primarily on the species category. Species and extinction are the important criteria, but species and geographical criteria are not satisfactorily covered. Rather, the statute of CITES is primarily based on listed endangered species and on laws promulgated in individual countries. This leads to a situation where in a particular species listed in CITES may be legally obtained and traded from one country, but not from another.

CITES Appendix I lists 675 critically threatened and endangered species. Commercial trade, in Appendix I species is totally prohibited. Any non-commercial transaction involving these species, say for instance for scientific research, is subjected to the issue of import and export permits. However, before issuing such permits, scientific authorities between the two countries must certify that the transaction will not be detrimental to the survival of the species in question.

Appendix II lists, .species (and products derived there from), whole genera and even entire families of plants that are not as seriously threatened as those listed in Appendix I, but may become threatened if trade in them is not strictly regulated. Export of specimens listed in Appendix II requires an export permit, which may only be issued on the approval of the scientific authority of the concerned country. This authority must state in the approval certificate that the trade in that particular specimen will not be detrimental to the survival of the concerned species. A total of 21,000 plant species and 3700 animal species are listed in Appendix n. The plant families included are

Cataceae, Cyatheaceae, Cycadaceae and Orchidaceae. Virtually all countries do trade in Appendix II species but Indonesia, Philippines, Thailand, Argentina, Bolivia, Guyana, Cameroon, Tanzania and Mali have the heaviest exports. The most important taportog countries are the USA, European countries, Japan, Singapore, Hong Kong, China and Taiwan.

Appendix III lists those species which are rare in one country but fairly common in others. CITES provides the option for countries to restrict trade in these species and allow export only on specific export permits. Import of these taxa into any country requires presentation of a certificate of origin as proof that the species in question does not originate "from a country for which this species is listed as rare. Among the 50,000 species or 'so included in this Appendix, the only plant taxa are five species of trees from Nepal.

All the legal provisions of CITES apply not only to whole live or dead specimens of listed species, but also to their readily recognisable parts and derivatives; however, a small number of exceptions are listed. CITES arranges conferences for the signatory parties once every two years. It has a permanent secretariat, for which support is provided by UNEP. It is based in Switzerland. Most countries have now ratified CITES. Turkey, Mexico and New Zealand are some of the notable countries that have not yet become a party to CITES.

International trade in wild species and its products is now worth more than 4-5 billion US dollars per year. In fact, it is the second largest illegitimate business after narcotics. In a typical year, it is estimated that at least 38 million plants are imported into the USA alone, many without valid permits and CITES approval. However, there are several instances in which CITES has been highly successful in controlling the illegitimate trade and extinction of specific taxa. The role of CITES, therefore, is to provide the nations of the world a legal framework for combating the illegal trade in endangered taxa.

There have been, expectedly, many problems in the proper and strict implementation of CITES. Some have been removed through increased co-operation between trading nations, recommendations in national and international conferences, and effective action by the CITES secretariat. Other problems continue unresolved. The most important among the remaining problems are: (i) better enforcement of CITES' legislation' (ii) avoidance of overemphasis on animals to the neglect of plants", (iii) preparation and provision to enforcement officers of good identification manuals for the plants listed in CITES; a customs official may not know the difference between, for example, *Cattltya skinneri* (listed in Appendix I) and C. *forbesii* (listed in Appendix II). Once illustrations are available, suspicious plants could be referred to knowledgeable authorities; and (iv) strengthening import and export control machinery at all levels. The almost global acceptance of CITES, very encouraging indeed, should not make us complacent There are very clear loopholes in the biodiversity legislation of many countries that permit them to evade the spirit of CITES.

Several incidences are also known wherein CITES norms were not strictly implemented by customs officials. The CITES document itself may threaten species. There are no real problems with either Appendix I or HI of CITES, but the restrictions applied to Appendix II may be harmful to the long-term survival of endangered species. Reports from Mexico and some parts of Latin America state that when clearance is given for development of agricultural fields, native plants are left to rot in heaps at the edge of fields due to trade restrictions. Thus, CITES covers international trade but does nothing to protect taxa in the home country. Restriction of trade at the international level with no protection at home vitiates the spirit of conservation; species can still be destroyed. CITES unintentionally impedes the rescue of many tropical orchid species as well. Since they cannot be traded with other countries due to the blanket protection provided by Appendix III of CITES, they are doomed to extinction when the tropical trees on which they grow are cut down.

The major function of CITES May in reality turn out not to be restriction in trade, but rather in alerting lay government to international concern for endangered species. Awareness in a number of countries, still indifferent to the fate of their biodiversity, is a need of the hour.

Another organisation, called TRAFFIC (Trade Record Analysis of Flora and Fauna in Commerce) monitors international trade of species. The Indian unit was established in 1991 in the WWF-India headquarters in New Delhi. A few years ago, TRAFFIC conducted an experiment at major international airports of countries that are signatories to CITES to monitor how closely the provisos of CITES were adhered to. The experiment involved carrying a cactus plant through customs in several countries. The plant was either declared or prominently displayed at the customs counter. Only the US and the (former) Soviet Union confiscated the cactus. Confiscation was based, however, oh the absence of a proper phytosanitary or health permit and NOT the fact that all cacti are on Appendix II of CITES. Not one of the customs officers encountered during this experiment understood or even seemed aware of CITES, in spite of the fact that some officers did have a copy of the CITES document near-by.

Ramsar Convention

Also called the Convention on Wetlands of International Importance, the Ramsar Convention is an international treaty drawn up an 1971 at Ramsar in Iran. The convention came into force in December; 1975. This convention expects its contracting nations to promote the wise use of wetlands situated in their territory; it also requires the contracting parties to designate certain wetlands for inclusion on a list of wetlands of international importance. Such wetlands of international importance are called Ramsar Sites. The contracting nations should mandatorily make national wetland inventories-they should also establish nature reserves on wetlands and provide adequately for their maintenance. It is also expected that the nations should train personnel to manage and research wetlands. The contracting parties are further obligated to maintain the ecological character of the listed wetlands. In other words, the convention provides for the international cooperation for wetland conservation. The major parameter for a wetland to qualify for inclusion in the international list is the presence in it of rare, vulnerable, endangered or £ndemic plants/ animals. As of 1994, 81 States were contracting parties to the Ramsar Convention and 654 Ramsar wetlands have been designated covering an area of more than 43 million hectares (Navid 1994).

A 'Wetlands Conservation Fund' was established to assist countries in implementing the objectives of the Ramsar Convention. Funding is provided only to those countries that have contracted for wetland conservation activities relating to any one of the following fields: improvement of management of Ramsar Sites designation of new Ramsar Sites, promoting wise use of wetlands, training personnel in wetland management and organising promotional activities such as seminars, workshops, educational programmes etc.

International Undertaking on Plant Genetic Resources and Farmers Rights

The International Undertaking on Plant Genetic Resources (IUPGR) was adopted in 1983 to strengthen the rights of suppliers of genetic resources and to counterbalance the increasing protection of technology emanating out of genetic resources (Virchow 1998). This undertaking ruled that genetic resources should not be freely accessible under the slogan that 'plant genetic resources are a heritage of mankind'. IUPGR is a non-binding agreement and hence initially many countries paid it scant heed. From 1987 the IUPGR has added some Annexures including Farmers' Rights. As of May 1997, 111 countries have adhered to the tenets of the IUPGR; notable exceptions are Brazil, Canada, China, Japan, Malaysia and the USA. IUPGR assures the conservation, use and availability of PGRFA by 'providing a framework recognising the past, present and future contributions of farmers to the maintenance, improvement and provision of PGRFA' (Plant Genetic Resources for Food and Agriculture), a programme now known as Fanners' Rights. It provides for internalisation of benefits (i.e. sharing of benefits amongst farmer's themselves. without the benefit being usurped by others) through some kind of joint property rights (rights jointly held by the farmers). The Farmers' Rights infact envisage farmers themselves to hold the responsibility of conserving land races (Hardori *-et ah* 1994). Implementation of Farmers' Rights is hampered, however, by the lack of international funding.

UPOV Convention and Rights in Plant Varieties

Germany and the USA were among the only few countries before 1960 that gave international protection rights to plant varieties. But in 1961 due to pressure from plant-breeding industries, an International Union for the Protection of New Varieties of plants called 'Union pour la Protection des Ontentions Vegetales' (UPOV) in French, was formed in Geneva and the UPOV convention signed immediately. UPOV was established with a view to regulating international trade of protected varieties and ensuring that the member States acknowledge the efforts and achievements of breeders of new plant varieties by granting an exclusive property right (Hardon *et al.* 1994). Initially there were 10 contracting parties but subsequently several others joined the Convention. The UPOV Convention was revised in 1972, 1978 and 1991. The USA endorsed the Convention after amendments were made in 1972. Now there are 32 member states, of which 26 are in the process of implementing UPOV at the national level (FAO 1997).

Table 3.7: Comparison of main provisos of PRR under the UPOV Convention and Patent Law (from Swaminathan 1997)

Proviso	UPOV 1978 Act	UPOV 1991 Act	Patent Law
Protection coverage requirements	Plant varieties of nationally defined species • Distinctiveness • Uniformity • Stability	Plant varieties of all genera and species • Novelty • Distinctiveness • Uniformity • Stability	Inventions • Novelty • Inventiveness • Non obviousness • Industrial application and usefulness
Protection term	Minimum 15 Years	Minimum 20 years	17-20 years (OECD)
Protection scope	Commercial use of reproduction material of the variety	Commercial use of all material of the variety	Commercial use of protected matter
Breeders exemption	Yes	Not of essentially derived varieties	No
Farmers privilege	In practice,yes	Up to national law	No
Prohibition of double protection	No species eligible for protection can be patented		-

The UPOV Convention requires that each country adopt within eight years of becoming a member, national legislation ensuring protection to at least 24 genera or species, in accordance with the provisos of the Convention. A plant variety is protectable under the UPOV system if it is distinct, uniform and stable (DUS) and satisfies a novelty requirement. DUS criteria are checked by the national authority responsible and usually by growing the variety over at least two seasons.

Duration of protection depends on the national legislation and on the species to which the variety belongs, but generally for 20-30 years. In addition to the incentive to farmers in the form of exclusive rights, the UPOV system provides 'Breeders Exemption', i.e., the protected varieties are freely available for further research and development of new varieties. UPOV also confers on the holder the right to 'sell the reproductive material' (e.g. seeds, cuttings, whole plant) the protected variety, but not 'consumption material'. (e.g. fruit)(See Table 3.7 for more details).

ITTA and 1TTO

ITTA stands for International Tropical Timber Agreement. It came into force on 1st April 1985. The contracting parties entered into the agreement recognising the importance of, and need for, proper and effective conservation and development of timber forests' and concomitantly ensuring optimum utilisation of such forests in a sustainable manner and maintenance of ecological balance. Tropical ' timber reforestation and forestation are encouraged at national and international levels and more than 66 projects and 35 pilot studies on these aspects have been approved and supported.

Problems Related to the Legal Status of Plants

The legal status of plants invariably compounds the problem of strict enforcement of biodiversity laws. It is very different from the legal status of animals, and is relatively more ambiguous. Wild animals are usually characterised by law as res *nullius* (Given 1996). This concept, borrowed from Roman law, emphasizes that animals, especially wild ones, cannot *be* subject to ownership even by the land on which they occur, unless they have been legally obtained. In some countries, more recently enacted laws have replaced this Roman concept of the legality of animals, by characterising wild animals as public property. Whether such a change would affect better conservation of animal’s remains to be seen: Plants, in contrast, are rooted to a place and whoever owns the place is the owner of the plants as well; the owner is therefore free to exploit his plants in whatever way he or she wants. This, however, does not apply to certain specific taxa of plants in some countries. In India for example, sandalwood tree is the property of the government wherever it grows.

Public or private ownership of wild plants, perhaps with the exception of trees and a few other economically useful taxa, generally does not suffice *per se* to discourage their collection or destruction by third parties. People continue to collect wild species of plants even from private lands and this freedom, in fact, is embodied in legislation or even in constitutions in countries such as Norway, Switzerland and Bavaria. Thus it becomes practically very difficult to enforce biodiversity laws with reference to wild plants (Given 1996).

The other problem concerning the legal status of plants is the group ownership of particular areas such as pastures, tank and river bunds etc. In many parts of the world, especially in Western Europe and Japan, pastures, for example, are the common properties of a group of persons, usually a village group (Bromley 1986; Runge 1986). In India and some South-east Asian countries large areas of land are under the ownership of temples or under government and quasi-governmental control; the latter is true of 'wastelands'. Such ownership is traditionally passed on through several generations and is often based on custom and not on written law. Therefore, it becomes the right and duty of every member of the village group to safeguard the common property; and calls for joint decision making on any issues arising out of these properties (Oakeson 1986). The problem with common ownership is that attention is focused on the conservation and sustainable utilisation of only a particular bioresource in the property and that the preservation of non target species is not considered; in fact the latter are often destroyed with impunity (Given 19%).

In conclusion it may be stated that wild plants, when occurring in a private property, can be destroyed by their very owners, and when occurring as open access resources can be collected or even destroyed by anyone almost anywhere. Therefore, any legal protection to wild plants should be viewed against these backgrounds (Given 1996).

Plant Collection and Trade Controls

Uncontrolled mass collection of wild plants, especially of slow-growing or rare categories, can contribute significantly to their depletion or even extinction in the wild. The extinction of *Tricholepidea adamsii*, an endemic mistletoe of New Zealand (Given 1996), and of *Tecophilaea cyanocrocus*, an endemic Liliaceae member of Central Chile (Chilean Forest Service 1989), are documented examples of species lost due to over collection.

Uncontrolled collection of wild plants was mainly due to the development of trade particularly international trade, in many species for the extraction of drugs /medicine, for ornamental or for educational/research purposes. A documented example for the first is *Rauwolfia-serventinai* a plant-of very GREAT medicinal potential, now almost extinct from natural localities in India, and for the second may be cited many orchids, cacti and lilies. A very important category of uncontrolled collection is known from many South-east Asian countries such as India. In many universities/colleges it was (and is even now in some places) mandatory for every student to submit herbarium sheets of wild plants representative of as many taxonomic groups he was studying as possible. On average, a post-graduate student would submit 300 different species of plants, and there were about 400 post-graduate students specialising in botany in southern Indian universities alone every year. This was almost the sole reason for depletion of plant wealth in many parts of the Himalayas and the Eastern and Western Ghats in southern. India. Fortunately, this practice has been discontinued in some universities and other universities have restricted the number of herbarium sheets to be submitted by each student to a maximum of 50.

Laws have been enacted in several parts of the world to enforce partial or total collection controls. Total control consists of an absolute prohibition to collect whole plants or parts thereof of those taxa enlisted in the threatened category. Exceptions are generally made for scientific research, subject to granting of special permits. Partial controls prohibit the uprooting or digging up of subterranean parts or restrict the collection of aerial parts to a small number of twigs (often to less than 20 pieces). In many countries, lists of taxa that can be collected this way have been prepared. In several countries partial or total collection controls apply to all land, whether public or private, and to all persons including landowners. In certain European countries, this restriction does not apply to landowners, provided the plant to be collected is not traded. In Australia, Switzerland and South Africa, strict restrictions are imposed to collect any species of plant, whether useful or not; collection is allowed in a specified quantity using specified-collection methods only after obtaining special permits (Given 1996).

Information on trade controls in fully or partially protected plant species was provided above in the section on CITES. For non-protected plant taxa, however, trade controls are very essential, supplemented by controls applied to all other links in the trade chain (Given 1996), such as licensing of traders, nurseries etc. Buying or selling of plants from persons other than licensed sellers or growers should be prohibited. Such trade controls exist, for example, in parts of Australia and South Africa. Ideally, laws should be uniformly enacted at a national level since interprovincial or interregional trade within a nation may not pose problems. As a good example the Lacey Act of the USA may be cited. Uniform National level legislation cannot be enacted in countries such as Australia for constitutional reasons.

National Legislation

Much legislation has been enacted in different nations of the world to strive to protect important habitats and biodiversity elements. Although beset with considerable political and practical difficulties, and remaining almost always deliberately ambiguous and largely ineffective (Given. 1996), such legislation does help in conservation efforts. As an example may be mentioned the UK Wildlife and Countryside Act. Furthermore; very strict and effective legislation does exist in some countries, for instance the Irish Nature Conservation Act, the Swiss Canton of Zurich, Finland's law on land-use, the French Nature Protection Act of 1976 and Denmark's land-use laws.

Biodiversity Information: Management and Communication

Introduction

Readers have to understand that there is an urgent need for resonance between the needs of biodiversity science and scientists on the one-hand, and databases on the other. Biodiversity workers live throughout the world and are all interdependent. They need information, and not just local, but regional and international as well. Moreover, biodiversity science depends critically on high-level concepts on biomes, ecosystems, floras and faunas, hot spots, genetic resources, alien taxa etc. (Bisby 2000). Hence a strong effort for the collection, documentation, management and distribution of biodiversity information is needed so that effective decisions on managing bioresources can be made..Such information is also required for enacting national and international legislation and laws.

The use of biodiversity information is triggered by three principle categories of motivations: public policy (involves compliance with laws, rules, legislation, regulations and/or treaties), private sector (needed to advance commercial interests relating to breeding, ecotourism, bioprospecting involving biotechnology etc.) and public interest and cultural motivations (to advance the conservation and sustainable management of bioresources). The important aspects involved here are data collection, from the real world, storage of data, analysis of organised and integrated data (if necessary mathematical modelling as well) so as to obtain useful and pertinent information, derivation of knowledge from such information through further analysis, interpretation and understanding and finally the attainment of wisdom (here, taking wise, proper and efficient biodiversity management initiatives and actions) through the intelligent use of knowledge. The author is reminded here of the famous poem 'Choruses from the Rock' by T.S. Elliot.

- Where is the Life we have lost in living?
- Where is the wisdom we have lost in Knowledge?
- Where is the knowledge we have lost in information?

To these lines of T.S Elliot the following might be added:

- Where is the information we have lost in data?
- Where is the data we have lost in databases?

Libraries

These are the main sources of information provided through collections of both published and unpublished, literature, and facilitating its exchange- Most libraries are regional and at best national. However, there are several international libraries. The most important among them are those located at the Asian Institute-of Technology, CGIARs (which have separate centres for forestry, tropical agriculture, maize and wheat improvement, potato and plant genetic resources), Institute Francais de Recherche Scientifique pour le Development en cooperation, International Centre for Integrated Mountain Development, International Centre for Living Aquatic Resources Management, International Development Research Council, International Waterfowl and Wetlands Research Bureau, National Library of Agriculture (USA), The Natural History Museum (UK), Royal Botanic Gardens Kew and Edinburgh (UK), Smithsonian Institution (USA and Panama), UNO, and IUCN—The World Conservation Union. Most of these libraries are thematic, but all provide Vital information on biodiversity.

Bibliographies

Information relating to biodiversity is found in the literature pertaining to biological sciences, forestry, agriculture, wildlife and conservation' biology as well as in the literature on economics, social sciences and even on legislation and law These can be searched using the key words 'biodiversity' and 'biological diversity'. In addition, biodiversity information can be found in the so called 'grey literature' (i.e., reports from NGOs; consultative groups and govt. departments). Most of this grey literature is unpublished and extremely difficult to trace.

Periodicals

Several periodicals contain articles on biodiversity. The names of the most important appear in Ulrich's International Periodicals Directory. In addition, several newsletters are available. The most important periodicals are listed below.

- Biodiversity Letters
- Biological Conservation
- Conservation Biology
- Ecology
- Oikos
- Oecologia
- Journal of Biogeography
- Journal of Ecology
- AMBIO
- Annual Review of Ecology and Systematics
- Ecography
- Trends in Ecology and Evolution
- Biodiversity and Conservation
- Biotropica
- Biodiversity
- Threatened Plants Newsletter
- Journal of Intellectual Property Rights
- BDM Updates

Databases

Data refers to 'observations, measurements or facts referenced to some kind of accepted standard, which are subsequently integrated, processed, interpreted or otherwise manipulated to produce information' while Information is the knowledge (product) derived from the analysis and interpretation of data' (Busby 1997). Data should be stored, managed and readily made available for integration with other data so that information can be generated from data easily and used as and when required for whatever purpose.

All the nations of the world have now more than adequately realised their wider regional and global responsibilities regarding their biodiversity wealth and conservation as well as the pressing need to manage the biodiversity information and data generated thus far. In addition, individuals, local communities, industries, NGOs and other institutions have also realised that to make proper decisions and manage biodiversity, they need to develop databases and their own information system frameworks. Details about biodiversity databases are given here.

The absolute need for effective organisation, management and use of data and information on biodiversity is already reflected in many international agreements and legislation such as the CBD, CITES etc. For example, as already stated, Article 7d of CBD indicates the requirement-to 'maintain and organise, by any mechanism, data ....' and Article 17 of CBD is concerned with the exchange of information. The CBD, however, has not laid down any operational framework for achieving information exchange. In response to the requirement of data management and information exchange on biodiversity, the UNEP and WCMC together designed and submitted to GEF the project proposal oh "Biodiversity Data Management (BDM) capacitation in developing countries and networking biodiversity information". The BDM is a UNEP/CEF project funded by GEF to the tune of US $4 million. This project was commenced in June 1994. The Bahamas, Egypt, Poland, Chile, Ghana, Thailand, China, Kenya, Costa Rica and Papua New Guinea were the ten countries that participated in the first phase of this project. The overall objective of BDM is to enhance the capacity building of developing countries biodiversity data management relating to the implementation of CBD. A subproject agreement was drawn up with WCK4C to prepare a set BDM support materials. A Guide to Information Management was prepared in addition to the Guidelines for National Institutional Survey. The Electronic Resource Inventory of UNEP provide a wide range of information and reference directories on software, hardware methodologies, standards, common practice data sources, key organisations and exempla projects related to biodiversity management.

There are many biodiversity related initiatives at the national level that are closely linked to the BDM project. These include Biodiversity Country Studies, Nation Biodiversity Strategies and Action Plan (NBSAP), National Environmental Action

Plan (NEAP), National Conservation Strategies (NG National Sustainable Development Strategies. National Tropical Forest Action Hans (TFAP National Forestry/Wildlife Master Plan Protected Area Systems Plans etc. The BDI Newsletter 'BDM UPDATE' provides complete information on relevant issues and events.

Taxonomic Databases Working Groups for Plant Sciences SA2000 and other Taxonomic Databases

Taxonomic Databases Working Group (TDWG) was established by the untiring efforts of Dr. V.P. Heywood, a noted plant taxonomist, in 1980, TDWG seeks to create worldwide mechanism for data exchange between botanical database through the agreement of data models, data structures and standards, and data exchange mechanisms. TDWG has already published series of standards for areas, such as author names and abbreviations, geographical area; and an international transfer format for botanical garden plant records (Plant Taxonomic Database Standards No.l, Hunt Institute for Botanicacal Documentation, Pittsburgh) (ITF 1987). At the IUBS General Assembly in 1994, it was agreed to extend the activities of TDWG to groups other than angiosperms and some progress has been made. The ILDIS (International Legume Database and Information Service) has established a botanical diversity database for the17, 000 known legume species (Zarucchi *et al.* 1993). It is a co-operative project involving more than 20 research groups from five continents; the information system generated is available internationally. The readers are advised to refer to the following also: F.A. Bisby R.M. Polhill, J.L. Zarucchi, B.R. Adams and S. Hollis. 1994. Legumeline (ILDIS Phase I Database).

Box 3.4: The missions and goals of Systematics Agenda 2000 (from SA 2000, 1994 a, b)

Mission 1: To discover, describe and inventory global species diversity

- To survey marine, terrestrial and freshwater ecosystems to achieve a comprehensive knowledge of global species diversity;
- To determine the geographic and temporal distributions of these species;
- To discover, describe and inventory species living in threatened and endangered ecosystems;
- To target groups critical for maintaining the integrity and function of the world's ecosystems, for improving human health and for increasing the world's food supply, and
- To target the least known groups of organisms.

Mission 2: To analyse and synthesise the information derived from this global discovery effort into predictive classification systems that reflect the history of life

- To determine the phylogenetic relationships among the major groups of organisms,

thus providing a conceptual framework for basic and applied biology;
- To discover the phylogenetic relationship of groups of species that are critical for applied biology, targeting species I that are important for human health and food production, as well as for conservation of the world's ecosystems;
- To discover the phylogenetic relationships of groups of species that are of critical importance to the basic biological sciences, such as those having broad relevance for experimental science and those critical for maintaining the integrity and function of ecosystems, and
- To develop more powerful techniques and methods for systematic data analysis.

Mission 3: To organise the information derived from this global programme into an efficiently retrievable form to best meet the needs of science and society

- To develop systematic, biogeographic and ecological databases of species information based on species housed in the world's natural history collections;
- To integrate data from specimens housed in systematic collections with information contained in GIS databases, thus providing a means to monitor past and present effects of global change on species distributions and extinction;
- To develop linkages among databases for the efficient retrieval of all available information about species and the places in which they occur;
- Todevelopi and implement,an information system that can be accessed efficiently by a broad international user community;
- To develop data dictionaries of taxonomic names, geographic localities and other infonnation basic to all systematic databases;
- To develop data products, including guides, keys, electronic floras and faunas and monographic works, and
- To develop mechanisms for maintaining and updating databases and information networks including continuing hardware and software support.

Systematics Agenda 2000: Charting the Biosphere (SA 2000) is a programme not only aimed at discovery and research but also at documenting and synthesising knowledge about global species diversity within the next two to three decades. If is jointly compiled by the American Society of Plant Taxonomists, Society of Systematic Biologists and the Willi Hennig Society, in co-operation with the Association for Systematic Collections (SA 2000 1994a,b) and is supported by the US National Science Foundation (NSF). Twenty-seven Standing Committees involving over 300 scientists representing a broad array of institutions and specialities were/are involved in the SA 2000 studies. Details are summarised in Box 3.4.

The benefits expected from this ambitious programme are as follows: (i) attainment of more knowledge about an increased number of useful plants; (ii) an improved database, which will help in conservation and bioresource management; (iii) provision of knowledge to help in selection of new and improved crops of food and medicinal value; and (iv) to provide baseline data for monitoring global climate and ecosystem changes, rates of species loss etc. SA 2000 also aims at capacity building in developing countries to enable them to acquire /build collection-based infrastructures such as herbaria, seed/pollen/microbial/gene banks etc. SA 2000 also recognises the need for national research centres manned by professional systematist.

The NSF of US created in 1995 'Partnerships for Enhancing Expertise in Taxonomy' (PEET) (web: nhm.ukans.edu/peet). PEET initiated a new field of Biodiversity Informatics. A database known as 'SpeciesAnalyst' (habanero. nhm. ukans. edu.) was first established with information initially available with Kansas Natural History Museum collections. Subsequently collections available elsewhere were included to provide data on 12 million specimens. There is a proposal to increase it to 38 million specimens. 'Species Analyst' also forwards geographic information about a given species in each collection to the San Diego supercomputer centre. There, a programme called GARP developed by David Stockwell, maps that information and based on the *environmental* data available for those sites, predicts the species environmental niche and its overall distribution.

Other Databases on Biodiversity

Hundreds of databases on biodiversity have now been created throughout the world and space limitations preclude listing all of them here. The most important are mentioned below and, wherever needed, a brief description given.

- IOPI Work Plant Checklist (Bisby *et al.* 1993; Burnett, 1993)
- BIMS (Biodiversity Information Management System). A relational database for monitoring the conservation status of species, wildlife habitats and protected areas) (MaCkinnon 1994).
- BRAHMS (Botanical Research and Herbarium Management System). A database on botanical collection system.
- ENVIS (Environmental Information System, India).
- DIALOG. An on-line information source and the longest commercial system available; it contains more than 450 databases containing more than 350 million articles from over 2500 journals; if also contains details on more than 15 million patents and on more than 10 million chemical substances.
- Abstracts of Tropical Agriculture (ORBIT)
- Agricola (DIMDI, Data-star/Dialog) (viii) AGRIS International (Data-star/Dialog, DIMDI, ESA-IRS)

- Aquatic Sciences and Fisheries (Data-star/ Dialog, DIMDI) (x) Biological and Agricultural Index (BRS)
- BIOSIS Previews (Data-star/Dialog, DIMDI)
- GAB Abstracts (Data-star/Dialog, DMDI)
- GEOBASE (Data-star/Dialog, DIMDI)
- Life Sciences Collection (Data-star/ Dialog, STN International)
- Microbial Information Network Europe (DIMDI, Deutsche Sammlung von Mikroorganismen und Zellkulturen, Gmbtt) (also abbreviated as MINE)
- Oceanic Abstracts (Data-star/Dialog, STN, ESA-IRS)
- Remote sensing on-line retrieval systems (ORBIT, ESA-IRS)
- SciSearch (Data-star/Dialog, DIMDI)
- UBIB UNESCO Bibliography (ECHO) (xx) SEPASAL (Survey of Economic Plants for Arid and Semiarid Lands) Database by Royal Botanic Gardens, Kew/Surrey.
- The Chapman and Hall Chemical Database by Chapman & Hall Publishers
- NAPRALERT (Natural Products Alert)
- MEDFLOR (for ethnobiology)
- Neogene Marine Biota of Tropical America. Logs marine fossils from the last 25 million years (porites.geology.uiowa.edu/index.htm).
- Evolution of Terrestrial Ecosystems (ETE). Database developed by the Smithsonian National Museum of Natural History and Hohn Damuth of the University of California, Santa Barbara. It covers both animal and plant terrestrial fossils and includes data on age, species lists, body sizes and diet for nearly 4000 localities, largely from the African Late Coenozoic (web: etedata.si.edu.).

Of the 7500 databases available worldwide(as of 1995), 75% are related to biological sciences, of which more than 60% aids bibliographic or directory, type and the rest are numeric, textual, image or multimedia. Most of these databases, with few exceptions, are available in print, CD-ROM, tape and on-line mode. Though the majority addresses the global need of users, those developed in the USA, UK, Canada, Australia and European countries satisfy local user needs too.

Distribution of Biodiversity information

If has now become possible to build, comprehensive and integrated biodiversity information systems on networks even though a huge amount of work has yet to be done. Solutions to key issues such as primary attribute data, standards, metadata, custodianship, data management tools, networks etc. are already well developed (Canhos *etal. 1997;* Olivieri *et al.* 1995). Information is becoming more digital and networked network publication has become the order of the day. Examples: the Bioline publications (http://www.bdt.org.br/bioline/), 'Tree of Life' (http://phylogeny.arizona.edu/ tree/phylogeny.html) and 'Phylogeny of Life (http://ucmpl.berke4ey.edu/alllife/ threedomains.html)./Addresses for electronic journals and newsletters on biodiversity available in the Internet can be found at Electronic Journals VL (http://www.edoc.com/ ejournal/) and New Jour websites (http:// gort.ucsd. edu/newjour/).

The network tools and applications available include Tools using computer networks such as Electronic mail (e-mail), LISTSERV (extension e-mail) and USENET, as WELL S more popular Network Information Retrieval (MR) tools such as Telnet, File Transfer protocol (FTP) (a powerful data exchange tool), Wide Area Information Server (WAIS) (helps in retrieving information by searching indexes of databases), GOPHER (retrieves information through graphic interface), Veronica (acronym for Easy Rodent-Oriented Network Index to computer (Archives), and www (worldwide web).

Digital Libraries have also come into prominence, where very effort is being made to open the way to weaving electronic journals and scientific libraries into a single interconnected database. The Digital Library Initiative (DLI) is a project partly-sponsored by the US National science Foundation (NSF), NASA and the Advanced Research Projects Agency (ARPA) (http://walrus.stanford.edu/ diglib/pub/ nsf.announce.html.)

The best-known computer network is the internet, a network of networks. The Regional Map to Internet Connectivity (http:// info. isoc.org:80/images/mapvl4.gif) is regularly updated by the Internet Society, and the international E-mail Accessibility page (http:// www.ee$_r$ic.uk/misc/country-codes.html). This www.eeic.uk/misc/country-codes.html). This has enabled organisations throughout the world to discover new opportunities provided by the information infrastructure and to nurture their development through the establishment of discussion lists, on-line databases, metadatabases, Virtual Libraries (VL), Special Interest fretworks (SINs) and Search engines (Canhosefal.1997).

Metadatabases

It is well known that data and information on biodiversity are rapidly increasing. Several databases are now available throughout the world: Therefore, a central goal, of biodiversity informatics is to develop systems that permit interoperability and knowledge synthesis across a wide array of local/regional systems (Bisby 2000). This has forced the need to use metadata, i.e., data about data. Metadatabases hold data about data and are analogous to library catalogues. They facilitate the discovery of existing datasets in institutions and provjde additional information about contents, quality and features of the datasets. Good examples of metadatabases are the National Spatial Data Infrastructure (NSDI) provided by the Federal Geographic Data Committee (http:// fgdc.er.usgs.gov/), UNEP's GRID Database (http://www.inpe.br/grid/home) and CIESIN (http://www.ciesin.org).

GRID (Global Resource Information Database) is a system of cooperating centres within UNEP dedicated to making environmental information more readily accessible to environmentalists and decisionmakers and fosters the use of Geographical Information Systems (GIS) and Satellite image processing as tools for environmental analysis. Other metadatabases include the European Environment Agency of the European Union (for environmental data), IUCN Environmental Law Centre (for environmental and biodiversity legal aspects), NASA Global Change Master Directory (for data on global changes), Global Environmental Network Information Exchange (GENIE), Global Land Information System (GLIS) (for data pertaining to the Earth's land surface), Global Environmental Information Exchange Network or INFOTERRA (to facilitate exchange of information on environment), IPGRI (Directories of Germplasm Collections), HEMDisk of UNEP (information on environment monitoring agencies), World Federation for Culture Collections (WFCC) (data on microbes), ICSU's World Data centres, fossil records on worldwide web (http://sunrae.uel.ac.uk/ palaeo/pfr2/pfr.html), plant viruses (http:// life.anu.edu. au/./viruses/virus.html), nucleic acid sequences (fly.bio.indiana.edu /ll/ genebank-sequences) etc.

The most recent and complete metadatabase effort is the Global Biodiversity Information Facility (GBIF) (Bisby 2000; Edwards *et al.* 2000). This provides for interoperability by attempting to draw together basic biodiversity accession records from dispersed sites such as ERIN and Taxaserver (both from Australia), ENHSIN (European Natural History Specimen Information Network) (www.nhm.ac.uk/ science./rco/enhsin), ITIS (Integrated Taxonomic Information System) (www.itis.usda.gov), URMO (UNESCO-IOC Register of Marine Organisms) (www2.eti.uva.nl/database/urmo/ default.html), IOPI (International Organisation for Plant Information—a global plant checklist) (http://bgbm3.bgbm.fu.berlin.de/iopi/gpc), lEM (International Plant Names Index) (www.ipni.org/), CONABIO (Comision National para el conocimiento y Uso dela Biodiveridada of Mexico), (www.conabio.j;ob.rrix/), INBio (Instituto National de biodiversidad) (www;inbio;ae:cr/)v ABIF (Australian Biodiversity Information Facility. (www.anbg.gov.au/abrs/abif.htm)j, DTVERSITAS of UNESCO, OBIS (Ocean Biogeographic Information system), 'Tree of Life' (http:/ /phylogeny.arizona.edu/tree/ phylogeny.html) and 'Tree Base' (http:// herbaria.harvard.edu/treebase/).

Species 2000 is a global metadatabase programme to compile a 'Catalogue of Life' using distributed networking on the Internet. The main aim of this effort is to create a uniform and validated index to the world's known species of plants, animals, fungi and microbes, one for each group of organisms, in the name of Global Species Databases (GSDs). Species 2000 was established by IUBS, ICSU, CODATA(Committee on Data for Science and Technology) and IUMS. Itis endorsed by UNEP. It is planning to work closely with GBIF. Species 2000 will involve URMO, ITIS, IOPI, NAPRALERT/ NCBI (National Centre for Biotechnology Information, US), GRIN (Genetic Resources Information Network, USDA), SINGER (System-wide Information.-Network for Genetic Resources) (www.singer.cgiar.org), Flora Base (Plants of Western Australia) (http:// florabase.Calm.wa.gov.au), ERMS (European Register of Marine Species), (http://erms.biol.soton.ac.uk), etc.

Virtual Libraries

Virtual libraries (VL) are organised sets of links to items (documents, software, images, and databases on the networks, enabling users to find information that exists elsewhere on the network from one central (‘virtual’) location. The Worldwide Web Consortium (http: /m www.w3.org/pub/WWW/) holds the www Virtual Library (http:// www. w3.org/l hypertext/Data Sources/by Subject/ Overview.html). This is a distributed subject catalogue and includes a list of virtual libraries on a number of subjects, including those related to biodiversity. The other important virtual libraries are 'Biosciences' located at Harvard University, Cambridge, Mass, USA (http:// golgi harvard edu/biapages;html), and 'Forestry' (http://www.metla.fi/info/vlib/ Forestry.html). The section on Biodiversity, Ecology and the Environment is maintained by Bryant and Thornhill at the University of California, Irvine, CA, USA (Burley *et al.* 1997), while the www virtual library for fungi is: http://www.keil.ukans.edu/~fungi/.

Special Interest Networks

As a result of CBD and also to comply with the obligations of the Convention, individual countries have established/are starting to establish several specialised networks at country, regional and international levels. ERIN, the Environmental Resources Information Network from Australian Nature Conservation Agency, Canberra (http://kaos.erin. gov.au/ erin.html) is one of the exceptions in that it was established even prior to the Rio Convention. The others are from Costa Rica's INBio, the National Biodiversity institute (http://www.inbio.ac.cr/) and the USA (http: / /straylight.tamu.edu/ bene/ bene.html). The INFOTERRA of the UNEP consists of 170 national nodal points coordinated from Nairobi. In 1992, the idea to establish global computer networks for biodiversity data took the shape of an initiative known as BIN21 (Biodiversity Information Network, Agenda 21) (http://www.bdt.org.br/ bin21.html). Several new national developments emerged as BIN21 nodes: FINBIN, the Finnish Biodiversity Information Network (http:// www.csc.fi/biodiv/intro.html); CBIN, the Canadian Biodiversity Information Network (htlp:/ www.doc.ca/ecs/biodiv/biodiv.html); BEM-Br, the Biodiversity Information Network, Brazil (http://www.bdt.org.br/ index/binbr/) etc.

Unlike other initiatives, BIN-Br is coordinated by an NGO, the Andre' Tosello Foundation for Tropical Research and its tropical database. The other databases include the Long-term Ecological Network (LTEN) based in the University of Washington and the projects in Capacity Building for Biodiversity Information

Management begun by World Conservation Monitoring Centre (WCMC) based in UK, and the BioNET-International proposed by CAB International to pool the global resources in biosystematics. With support from UNDP under CAPACITY 21, a large number of Sustainable Development Networks are in the planning stage. Recently several special interests groups and networks (SIGN) dedicated to biodiversity conservation have sprung up all over the globe.

The most important are: http:// conbio.bio.uci.edu/orchid/ (orchids), http:// www.lab.s.agilent.com./bot/ep_home (carnivorous plant database with photos), http:/ /www/issg.org/database/welcome (global invasive species database), www.limn6l6gy.org (limnology), http://www.mobot. Org/MOBOT/ tropicos/moss/, http://www:nybg.org/bsci/ hcol/bryo/ (bryophytes), http:/-/ice. ucdavis.edu.USJSTational Park Service/; http: //w ww. conservationorg/science/cptc/ consprio/!run_me!.htm (Conservation International—regional conservation analysis project), http://www.inbio.ac.er/ATBI> (All Taxon Biodiversity Inventory), http:// www.eti.uva.nl/Database/WBD.htiril (World Biodiversity Database), http:// www.nhm.ac.uk/info/liKkS (Links to Natural History), http://esa.sdsc.edu/biodiv2.htm (Pact sheet from Ecological Society of America), http: / / esa.sdsc.edu/issues4.pdf. (Official publication on biodiversity by Ecological Society of America), http://www.abi.org/ (Association for Biodiversity Information http:// www.nature.nps.gov/im. (National Park Service environmental monitoring protocols and lists), http://www/epa.gov/ceiswebl/ceishome/ atlas/bioindicators. (Bioindicators), http:// www.uspto.gov/ wed /off ices / ac / ido / oeip / taf/top97cos.htm (website for obtaining details on leading Patentees in the USPTO), http:// www.nybg.org/bsci/hcol/fung/ (Catalogue of Fungi).

CHAPTER- IV

PRINCIPLES, THEORY OF TOLERANCE, CONTINENTAL DRIFT AND PLATE TECTONICS

The science dealing with the origin, distribution, and environmental inter relationships of plants is known as phytogeography, very much allied to ecology and geography. There are two major approaches to the study of phytogeography (i2 descriptive or static phytogeography-dealing with the Description of flora and vegetation of different botanical areas, and (ii) interpretive or dynamic phytogeography dealing with interpretations of causes of plants' distribution. With a descriptive approach, we will deal first with the major plant communities (biomes) of the world, and different vegetational belts of the earth constituted by these biomes together with characteristic climatic conditions of the area. This would then be followed by a descriptive account of flora and vegetation of India.

Major Plant Communities of World

Major plant communities of the world in general are classified chiefly on the basis of the kinds of habitat and environmental conditions into following chief types: (i) aquatic, and (ii) terrestrial communities.

Aquatic communities

Major part of the earth's surface is occupied by aquatic environments, with different kinds of plant communities. The chief types of aquatic plant communities are.

1. Freshwater communities.

They occur in freshwater habitats. The habitats may be (i) lentic (standing water), such as lake, pond, swamp and bog, or (ii) lotic (running water), such as river, spring, stream etc. These all cover hardly one per cent of the earth’s surface. The chief components of the plant communities are seed plants (submerged, floating and emergent), and phytoplanktons (floating green plants), such as diatoms, desmids, blue-green algae, green algae, green protozoans and green flagellates.

2. Marine communities

They occur in marine waters of seas and oceans. Oceans are continuous with each other and cover almost 3/4th of the earth's surface. The physical, chemical* ecological and biological aspects of oceans (oceanography) are very complex. The water temperature is as low as 0°C at poles and the maximum being about 25°C in tropics. Light intensities are poorer at poles than received in tropics. The water contains 3-5% of sodium chloride and traces of all the essential elements including nitrogen, phosphorous and manganese.

The chief components of plant communities in such waters' are phytoplanktonic diatoms, green flagellates, micro flagellates, and profuse growth of green, brown, and red algae which together form the seaweeds. Some such seed plants as *Zostera* (eel grass) are also present. Brown algae are most conspicuous due to their large size.

3. Estuarine communities

These are found in a very interesting type of habitat-the transition zone between the freshwater and marine habitats, under strong influence of tidal actions. The plant communities of such habitats are constituted chiefly by such macrophytes as seaweeds, sea grasses and marsh grasses, benthic microphytes and some phytoplanktons.

Terrestrial communities (Biomes)

Terrestrial communities are generally recognised as larger units the biomes. In biome (major life zone) the life form of the climatic climax vegetation is uniform. The major biomes of the world are as follows.

1. Tundra

These biomes cover large areas of the arctic zone. There are two tundra biomes one in the palearctic, and another in the nearctic region. Many species are common in both the regions. The vegetation is made up of dwarf, treeless community 'the tundra'. The common plants are grasses, sedges, mosses and lichens, with occasional occurrence of dwarf birches *(Betula)* and willows *(Salix)*. The ground remains frozen except-for die upper few inches during die open season.

2. Northern coniferous forest biomes

They occur across bom NOrdi America and Eurasia, as thick belts of evergreen forests. The chief life form of die biome is evergreen tree, especially die spruces, firs and pines.

3. Moist temperate coniferous forest biomes

They occur along the west coast of North America from central California to Alaska. Although dominated by die conifers, these forests are quite different ecologically and in their floristic composition from die northern coniferous forests. These are also called temperate rain forests. *Tsuga heierophylla. Thuja plicata, Abies grandis and Pseudotsuga* are die major dominant trees. In south, *Sequoia* and in north, *Picea sitchensis* are prominent There are also epiphytic mosses.

4. Temperate deciduous forest biomes

These cover eastern North America, all of Europe and part of Japan, Australia and tip of South America. Beech, maple, oak, chestnut etc., are the dominant trees. Herbs and shrubs layers are well developed. A large number of plants producing pulpy fruits and nuts, such as acorns and beechnuts are common. Besides them, some conifers, chiefly pines, are also present in subclimax states.

5. Broad-leaved evergreen subtropical forest biomes

They are well developed in the warm-temperate marine climate of central and southern Japan, and may also be seen in Florida, along the Gulf and South Atlantic coasts. They indeed develop under conditions of high moisture with less pronounced differences in temperature between summer and winter: Under such conditions temperate deciduous forests give way to broad-leaved evergreen forest climax. Dominants plants are *Quercus virginiana,* magnolias, bays, and hallies, as well as such tropical species as *Ficus aurea, Lysiloma* and *Bursera. Sabal palmetto* is also common. Vines and epiphytes are also present.

6. Temperate grasslands biomes

These cover large areas of the earth, where rainfall is very low (10"-30"), unable to support forest life forms but higher than that of deserts. However, grasslands also occur in regions of forest climate where edaphic factors have changed. These grasslands generally occur in the interior of continents. In north America, this biome is divided into east-west zones where tall grasses *(Andropogon gerardi, Panicumvirgatum,Sorghastrum nutans* and *Spartina pectinata),* mid grasses *(A. scoparius, Stipa spartea, Sporobolus heterolepis, Agropyron smithii.Kaeleria cristdta* and *Oryzopsi***s** and short grasses *(BuchVoe dactyloides, Bouteloua graciles, B.* sp., *Poa*, and *Bromus* sp.) are the dominant species.

7. Tropical savanna biomes

Tropical savannas (grasslands with scattered trees or clumps of trees) are found in warm regions with 40"-60" of rainfall with prolonged dryseasonand common fires. They are extensively found in Africa, although also present in South America and Australia. Trees are less in number. Grasses, such as species of *Panicum, Pennisetum, Andropogon, and lmpetata* are dominants. The trees are species of *Adansonia,* arborescent euphorbias and palms.

8. Desert biomes

They occur usually in region with less than 10" of rainfall, or sometimes in regions with greater rainfall that is very unevenly distributed. They occur in Sahara, Australia, western north America, Tibet, Bolivia and Gobi. In central Sahara and Chile, there is little or no rainfall. Three life forms of plants are found in deserts (i) annuals, (ii) succulents, and (iii) desert shrubs. In some deserts, mosses, algae, and lichens may also be present on bare ground. Some blue-green algae may also be present on sands.

9. Chaparral biomes

These are present in mild temperate regions with abundant winter rainfall but dry summers. The climax vegetation consists of trees or shrubs with hard, thick evergreen leaves. Such communities are of common occurrence in California and Mexico, along the shores of the Mediterranean sea and long the southern cost of Australia. Dominant species are large in number depending upon the climate of the region. Fire is the chief factor responsible for the dominance of shrubs over the trees. Thus these communities may be partly, at least, a 'fire disclimax'. In California, *Adenostoma* and *Arctostaphylos* are common shrubs, with a number of evergreen oaks, either as shrubs or trees. The chaparral of the winter rain areas of the Mediterranean regions is locally called maccbie, whereas similar vegetation in Australia is called mallae scrub. In Australian chaparral, trees and shrubs of the genus *Eucalyptus* are dominant.

10. Pinon-Jumper biomes

These woodlands (pigmy conifers) occupy large areas in the interior of the great Basin and Colorado River regions of Colorado, Utah, Arizona, New Mexico, Nevada, and west-central California. Moisture is the critical factor. Rainfall of 10"-20” that is unevenly distributed is responsible for the stunted growth of *Pinus edulis, P. monophylla* and several species of *Juniperus.*

11. Tropical rain forest biomes

They occupy low altitude zones near the equator, where annual rainfall exceeds 80" or 90" distributed over the year with one or more relatively dry seasons. Such forests occur in three main areas.

i. The Amazon and Orinoco basins in South America (largest continuous mass) and the central American isthmus.
ii. The Congo, Niger, and Zambezi basins of central and western Africa and Madagascar,
iii. The Indo-Malay-Borneo-New Guinea regions.

Species composition in different regions may differ, but there are hardly any differences in general forest structure and ecology. These forests are highly stratified. Trees generally form three storeys scattered very tall emergent trees, canopy layer, and understorey stratum. Shrubs and herbs strata with a number of ferns and palms are less massive due to dense shade. Climbers, especially woody lianas and epiphytes are most profusely present. 'Strangler figs' and other arborescent vines are noteworthy in these forests/Species diversity is much pronounced.

12. Tropical scrub and deciduous forest biomes

These biomes develop in areas where moisture relations are intermediate between desert and savanna on one hand and rainforest on the other. They cover large areas. The chief climatic factor is the imperfect distribution of a fairly good total rainfall. They are common in Africa, Australia and Brazil. The vegetation is of thorn forests type.

Phy togeographic Regions of Worl d (Vegetational Belts)

On the basis of climatic and geographical conditions, the earth is generally divided into the following four broad vegetational belts, as the climate and vegetation are inseparably interrelated. These belts with their appropriate subdivisions are as follows: (i) arctic zone, (ii) north temperate zone, (iii) tropical zone, and (iv) south temperate zone.

I. Arctic zone

These are the areas near the poles. This zone is divided into two.

1. Arctic proper

This is around the North Pole and remains covered with ice whole of the year. Some algae, annual flowering plants, mosses, lichens are the chief components of vegetation. Details of the vegetation have been given under tundra biomes of the world.

2. Subarctic

It is a less defined zone from southern arctic to the northern limits of temperate zone. The vegetation is similar in North America and Euro Asian regions of subarctic zone. It is also very cold. Bogs are abundant, and small height trees, shrubs and herbs are common in June, July among conifers, *Betula* spp. and *Salix* spp. Ground vegetation is constituted by some pteridophytes, orchids, insectivorous plants; mosses and lichens. In Alaska, there are dense tall evergreen tree forests.

II. North temperate zone

This zone extends both in die eastern and the western hemipheres of earth. Extending roughly between 30°N lat. and 55^{0}NTat, it is divided into two major zones:

1. North temperate of the eastern hemisphere

This is turn is sub-divided into four zones.

a. *Western and central Europe*

It is demarcated in north by the subarctics and in south by Alps and British Islands. The forests are dominated by several gymnospermous tall trees, oaks, maples and chestnuts. Ground vegetation is composed of some orchids, wild roses, buttercups, and species of *Viola, Salvia* and *Dianthus.* At high altitudes trees are replaced by grassy vegetation with some herbaceous flowering plants.

b. *Mediterranean flora*

It is between 30° and 40°N latitudes south of mountain ranges in Europe and in Asia around Mediterranean Sea. Climate is of warm temperate type. Vegetation chiefly consists of important fruit trees, olives, nut trees and oranges. Some foreign palms, cacti, acacias are also common. In the Asian region of Mediterranean as in Arab countries, the vegetation is sparse with species of *Atriplex, Alhagi, Polygonum,* and *Phoenix dactylifera* being common.

c. Northern Africa

The region consists of northern parts of Morocco, Algeria, Libya and Egypt. Rainfall is scanty and vegetation is sparse. In cooler areas, on mountains, some conifers broad-leaved oaks, are common. In deserts, some herbs and shrubs occur. Succulent xerophytes and woody acacias are also common in the deserts. A part of Sahara desert belongs to this zone.

d. Himalayas, eastern Asia and Japan

The vegetation of Himalayas will be described later in this chapter. Tibet, China and Japan have different types of vegetation. In China most of the natural vegetation, has been replaced for cultivation use. In China and Japan there are several conifers, *Ginkgo biloba* and *Cycas* being common trees. Some *Rhododendrons, Cinnamomum camphora, Begonia.are* also common.

2. **North temperate of the western hemisphere**

It consists of part of U.S.A. and Canada lying mostly between north latitude 30° to 55°. The eastern coastal regions of these countries in the temperate belt have some very characteristic species like *Schizoea pusilla—a* tropical fern. The forests are commonly made up of conifers and deciduous trees. On lower altitudes, however, some wild cherries, plums, roses and orchids are abundant. In the New England region trees of *Ulmus americana* are abundant. In the southern parts of U.S.A., there develop rich forests of tall trees. In the Weston Rocky mountains and slopes on Pacific side, there are forests of various types. Some low lying areas are also present below sea level. There are vast deserts in southern Arizona and south-eastern California. The major forest trees in different parts are conifers. In north California there grows *Sequoia sempervirens* tallest tree of world. Ground vegetation is made up of *Salicornia herbacea, Rumex maritima, Monptropa uniflora,* species of *Saxifraga, Primula* etc. In the Coloradodesert of Arizona and south eastern California, there are several types of xerophytes.

III. Tropical zone

It includes tropical Africa, tropical Asia, Mexico and large areas of South America. It is divided into two, the paleotropic, and the neotropic.

1. Paleotropic

It comprises old world or eastern hemisphere tropics and has two botanical areas.

a. Tropical Africa

It is a large landmass of uneven topography. Sahara deserts belong to this region. Rainfall is little or absent. Mangroves, shrubs and small trees are the chief components. In the interior there may develop dense forests with tree species of *Ficus, Bombax* etc; and some legumes. On ground, there are present some grasses. In Africa, most remarkable plant is *Welwitschia mirabilis.* In central Africa, toward east many plants common to India also grow. These are *Borassus flabelliformis, Tamarindus indica, Ficus* sp., *Asparagus, Clematis, Phaseolus, Cassia fistula, Erythrina*-. Species of *Acacia, Albizzia, Zizyphus, Bauhinia* also occur in open forests.

b. Tropical Asia

It comprises Arabia, part of Pakistan, India, Burma, Ceylon, Thailand, islands of Indian Ocean etc. Indian vegetation will be described later in the chapter. In Arabia, most of the desert species are found. Several acacias and species *oiProsopis* are common. *Coffea arabica* is supposed to be the native of Arabia. Sri Lanka is rich in species diversity, where most of the land is under cultivation of rice, sugarcane, banana, mango, papaya etc. Ferns are the chief components of sparse natural vegetation. In Burma, Thailand etc., most of land is under rice cultivation. The common trees are jack fruit, orange, mango, banana, betelnut etc. In Malaya and adjacent areas i.e. Java, Sumatra, etc. there is heavy rainfall, where large varieties of palms are cbmmon. Some ferns are also present. Chief vegetation is tall tree forests with liainas, insectivorous plants. In Java, important trees are *Albizzia, Pterocarpus, Tamarindus, Bombax, Cassia, Dendro-catamus* etc.

2. Neotropic

It consists of Mexico and large area of South America. In Mexico with areas of low rainfall, xerophytes are most common. Much of the land is in use of cultivation of wheat, maize, fruit, and vegetables. At higher cooler altitudes, there are trees of *Pinus, Spruce, Quercus* and *Populus.* On mountain peaks grasses are most common. In wet areas there are mosses, bamboos, paints, orchids etc. In South America, there are extensive forests of 'flood forest' type, where the most common trees are *Bertholletia excelsd, Maximiliana regia* etc. Mangrove vegetation is also common; there are also found many epiphytes. On less wet areas forests of large leguminaceous trees are common.

IV. South temperate zone

It consists of extreme southern region of Africa, Australia, and New Zealand. In African area, the vegetation is chiefly made-up of ferns and gymnosperms. On lower wet regions *Salix* and *Phragmites,* and in dry regions species of some grasses and *Acacia* are common. In northern part of Australia, most of the species are similar to those found in South east Asia. Characteristic trees are palms, nuts, *Eucalyptus* and varieties of *Acacia, Casuarina.* Ground vegetation of some pteridophytes is also found. New Zealand forests are mostly made up of conifers together with ferns. One species of palm, *Rhopalostylis* is also present. There are also present several species of *Metrosidos,* New Zealand appears to be the richest in bryophytes.

THEORY OF TOLERANCE

I. Drought tolerance

Drought tolerance refers to the degree to which a plant is adapted to arid or drought conditions. *Desiccation tolerance* is an extreme degree of drought tolerance. Plants naturally adapted to dry conditions are called *xerophytes*.

Figure 4.1: Sedum is a drought tolerant plant whose specific adaptations include succulence and a waxy surface on its leaves and stems.

Adaptations to dry conditions

Drought tolerant plants typically make use of either C4 carbon fixation or crassulacean acid metabolism (CAM) to fix carbon during photosynthesis. Both are improvements over the more common but more basal C3 pathway in that they are more energy efficient. CAM is particularly good for arid conditions because carbon dioxide can be taken up at night, allowing the stomata to stay closed during the heat of day and thus reducing water loss. Many adaptations for dry conditions are structural, including the following.

- Adaptations of the stomata to reduce water loss, such as reduced numbers or waxy surfaces.
- Water storage in succulent above-ground parts or water-filled tubers.
- Adaptations in the root system to increase water absorption.
- Trichomes (small hairs) on the leaves to absorb atmospheric water.

Importance in agriculture

Arid conditions can lower the yield of many crops. Plant breeding programs for improved yield during drought conditions have great economic importance, and these programs may be broad in scope. For example, one study on soybeans currently being conducted by the United States Department of Agriculture is scheduled to span several years, with research taking place across that country, and has among its goals the identification of specific mechanism by which soybeans resist wilting and of the specific genes for drought tolerance.

Importance in horticulture

In landscapes in arid or drought-prone regions, drought tolerance is an important consideration in plant selection. Xeriscaping is an approach to landscaping first developed in Denver, Colorado, a region with hot, dry summers. The use of drought tolerant plants is essential to a successful xeriscape, which ideally requires no supplemental irrigation.

II. Desiccation tolerance

Desiccation tolerance refers to the ability of an organism to withstand or endure extreme dryness, or drought-like conditions. Plants and animals living in arid or periodically arid environments such as temporary streams or ponds may face the challenge of desiccation, therefore physiological or behavioral adaptations to withstand these periods are necessary to ensure survival. In particular, insects occupy a wide range of ecologically diverse niches and so exhibit a variety of strategies to avoid desiccation.

Desiccation resistance in insects is generally measured by the change in mass during dry conditions. The overall mass difference between measurements before and after aridity exposure is attributed to body water loss, as respiratory water loss is generally considered negligible.

Types of desiccation resistance

There are three main ways in which insects can increase their tolerance to desiccation: by increasing their total body water content; reducing the rate of body water loss; and by tolerating a larger proportion of overall water loss from the body. Survival time is determined by initial water content, and can be calculated by dividing water loss tolerance (the maximum amount of water that may be removed without resulting in death) by water loss rate.

Increasing body water content

Insects with higher initial body water content have better survival rates during arid conditions than insects with lower initial body water content. Higher amounts of internal body water lengthen the time necessary to remove the amount of water required to kill the organism. The way in which body water content is increased may differ depending on the species.

The accumulation of glycogen during the insect larval stage has been linked to increased body water content and is likely a source of metabolic water during dry conditions. Glycogen, a glucose polysaccharide, acts as an oxidative energy source during times of physiological stress. Because it binds up to five times its weight in bulk water, insects with increased levels of body glycogen also have higher amounts of internal water.

Reducing rate of water loss

Another strategy used to reduce the risk of death by dehydration is to reduce the rate at which water is lost. The three main ways through which insects can lose water are (1) the surface of the body (integument); (2) the tracheae (respiration); and (3) excretion, or waste products. The important feature in reducing water loss in land snails during inactivity is an epiphragm.

Integument

The exoskeleton or integument of insects acts as an impermeable, protective layer against desiccation. It is composed of an outer epicuticle, underlain by an endocuticle which itself may be further divided into an exo- and endocuticle. The endocuticle provides the insect with toughness and flexibility and the hard exocuticle serves to protect vulnerable body parts. However, the outer cuticular layer (epicuticle) is a protein-polyphenol complex made up of lipoproteins, fatty acids and waxy molecules and is the insect's primary defense against water loss.

Tracheae

In general, insects adapted to arid environments also have an impermeable cuticular membrane which prevents water loss. Therefore a majority of water lost to the atmosphere occurs via the air-filled tracheae. To help reduce water loss, many insects have outer coverings to their tracheae, or spiracles, which shut when open respiration is unnecessary and prevent water from escaping. Insects at a greater risk for water loss face the challenge of either a depleted oxygen supply or desiccation, leading to an adaptive increase in tracheal volume in order to receive more oxygen.

Excretion

Following feeding, most insects retain enough water to completely hydrate their bodies, excreting the remainder. However, the amount of water excreted differs between species, and depends on the relative humidity and dryness of the environment. For example, Tsetse flies maintained at a high relative humidity, and thus non-arid conditions, excrete fecal matter with approximately 75% water content whereas Tsetse flies maintained at a low relative humidity, and thus dry conditions, excrete fecal matter with only 35% water content. This adaptation helps minimize water loss in unfavorable conditions and increase chances of survival.

Behavior modification

In addition to physiological adaptations which increase desiccation resistance, behavioral responses of insects to arid environments significantly decrease dehydration potential. *Drosophila melanogaster* fruit flies, for example, will actively move to areas with higher atmospheric water content when placed in dry environments. Alternatively, the dung beetle buries food in underground chambers, thereby ensuring water and energy sources during periodically dry conditions.

Feeding location may also be altered to ensure body hydration. Some caterpillars preferentially feed on the underside of leaves, where microclimate has higher relative humidity. In a highly time-consuming activity such as feeding, these insects significantly reduce their chances of desiccation.

Cryptobiosis (Anhydrobiosis)

Cryptobiosis refers to the state of an organism that has no detectable metabolic activity, resulting from extreme and unfavorable environmental conditions; anhydrobiosis refers to the state of surviving the loss of (almost) all body water. Although this state is commonly observed in invertebrates, only one insect is known to be cryptobiotic (anhydrobiotic), the African chironomid *Polypedilum vanderplanki*. *Polypedilum vanderplanki* undergoes anhydrobiosis, a cryptobiotic state wherein the body is completely dehydrated. The larvae of *P. vanderplanki* inhabit rock pools which commonly dry out completely. In response, *P. vanderplanki* larvae enter an anhydrobiotic state during which changes in body osmolarity trigger the production of large amounts of trehalose. Due to its capacity for water replacement and vitrification, the accumulation of trehalose prevents the death of the larvae from water loss.

Forms of cryptobiosis

Anhydrobiosis

Anhydrobiosis is the most studied form of cryptobiosis and occurs in situations of extreme desiccation. The term anhydrobiosis derives from the Greek for "life without water" and is most commonly used for the desiccation tolerance observed in certain invertebrate animals such as bdelloid rotifers, tardigrades, brine shrimp, nematodes, and at least one species of chironomid (*Polypedilum vanderplanki*). However, other life forms, including the resurrection plant *Craterostigma plantagineum*, the majority of plant seeds, and many micro-organisms such as bakers' yeast, also exhibit desiccation tolerance. Invertebrates undergoing anhydrobiosis often contract into a smaller shape and some proceed to form a sugar called trehalose.

Anoxybiosis

Anoxybiosis isn't considered a form of cryptobiosis by some. It takes place in situations lacking oxygen, and involves the organism intaking water and becoming turgid and immobile. Studies of the survival rates of organisms during anoxybiosis have given conflicting results.

Chemobiosis

Chemobiosis is the cryptobiotic response to high levels of environmental toxins.

Cryobiosis

Cryobiosis is a form of cryptobiosis that takes place in reaction to decreased temperature. Cryobiosis initiates when the water surrounding the organism's cells has been frozen, stopping molecule mobility and allowing the organism to endure the freezing temperatures until more hospitable conditions return. Organisms capable of enduring these conditions typically feature the evolution of molecules that facilitate freezing of water in preferential locations, while prohibiting the growth of large ice crystals that could damage cells.

Osmobiosis

Osmobiosis is the least studied of all types of cryptobiosis. Osmobiosis occurs in response to increased solute concentration in the solution the organism lives in. Little is known for certain, other than that osmobiosis appears to involve a cessation of metabolism.

III. Shade tolerance

In ecology, shade tolerance is a plant's abilities to tolerate low light levels. The term is also used in horticulture and landscaping, although in this context its use is sometimes sloppy, especially with respect to labeling of plants for sale in nurseries. Shade tolerance is a relative term, and its use and meaning depends on context. One can compare large trees to each other, but when comparing understory trees and shrubs, or non-woody plants, the term takes on a different meaning. Even in a specific context, shade tolerance is not a single variable or simple continuum, but rather a complex, multi-faceted property of plants, since different plants exhibit different adaptations to shade.

Except for some parasitic plants, all plants need sunlight to survive. However, in general, more sunlight does not always make it easier for plants to survive. Where water is scarce, life can actually be easier in the shade. In direct sunlight, plants face desiccation and exposure to UV rays, and must expend energy producing pigments to block UV light, and waxy coatings to prevent water loss. Plants in shade have the ability to absorb far-red light (730nm). Red light gets absorbed by the shade intolerant plants, but the far-red penetrate the canopy, reaching the understory. The shade tolerant plants found here have the ability to absorb light at this wavelength.

Figure 4.2: Eastern Hemlock is a shade tolerant tree.

On the other hand, when less light is available, less energy is available to the plant. Whereas in sunny and dry environments water can be a limiting factor in growth and survival, in shade, energy (in the form of sunlight) is usually the limiting factor.

Herbaceous plants

In temperate zones, many wildflowers and non-woody plants persist in the closed canopy of a forest by leafing out early in the spring, before the trees leaf out. This is partly possibly because the ground tends to be more sheltered and thus the plants are less susceptible to frost, during the period of time when it would still be hazardous for trees to leaf out. As an extreme example of this, winter annuals sprout in the fall, grow through the winter, and flower and die in the spring.

Just like with trees, shade-tolerance in herbaceous plants is diverse. Some early-leafing out plants will persist after the canopy leafs out, whereas others rapidly die back. In many species, whether or not this happens depends on the environment, such as water supply and sunlight levels. Although most plants grow towards light, many tropical vines, such as *Monstera deliciosa* (and a number of other members of the *Philodendron* genus) initially grow away from light; this helps them locate a tree trunk, which they then climb to regions of brighter light.

Trees

In forests where rainfall is plentiful and water is not the limiting factor to growth, shade-tolerance is one of the most important factors characterizing tree species. However, different species of trees exhibit different adaptations to shade.

The Eastern Hemlock, considered the most shade tolerant of all North American tree species, is able to germinate, persist, and even grow under a completely closed canopy. Hemlocks also exhibit the ability to transfer energy to nearby trees through their root system. In contrast, the Sugar Maple, also considered to be highly shade tolerant, will germinate under a closed canopy and persist as an understory species, but only grows to full size when a gap is generated. Shade-intolerant species such as willow and aspen cannot sprout under a closed canopy. Shade-intolerant species often grow in wetlands, along waterways, or in disturbed areas, where there is adequate access to direct sunlight.

In addition to being able to compete in conditions of low light intensity, shade bearing species, especially trees, are able to withstand relatively low daytime temperatures compared with the open, and above all high root competition especially with subordinate vegetation. It is very difficult to separate the relative importance of light and below ground competition, and in practical terms they are inextricably linked.

IV. Halophyte (saline tolerance)

A halophyte is a plant that naturally grows where it is affected by salinity in the root area or by salt spray, such as in saline semi-deserts, mangrove swamps, marshes and sloughs, and seashores. An example of a halophyte is the salt marsh grass *Spartina alterniflora* (smooth cordgrass). Relatively few plant species are halophytes - perhaps only 2% of all plant species. The large majorities of plant species are "glycophytes", and are damaged fairly easily by salinity.

Adaptation to saline environments by halophytes may take the form of salt tolerance (see halotolerance) or salt avoidance. Plants that avoid the effects of high salt even though they live in a saline environment may be referred to as facultative halophytes rather than 'true', or obligatory, halophytes.

\For example, a short-lived plant species that completes its reproductive life cycle during periods (such as a rainy season) when the salt concentration is low would be avoiding salt rather than tolerating it. Or a plant species may maintain a 'normal' internal salt concentration by excreting excess salts through its leaves or by concentrating salts in leaves that later die and drop off.

Figure 4.3: *Spartina alterniflora* (cordgrass), a halophyte.

Halophytes as Biofuel

Some halophytes are being studied for use as "3rd generation" biofuel precursors. Halophytes such as *Salicornia bigelovii* can be grown in harsh environments and typically do not compete with food crops for resources, making them promising sources of biodiesel or bioalcohol.

V. Biosalinity

Biosalinity is the study and practice of using saline (salty) water for irrigating agricultural crops. Many arid and semi-arid areas actually do have sources of water, but the available water is usually brackish (0.5-5g/L salt) or saline (30-50g/L salt). The water may be present in underground aquifers or as seawater along coastal deserts. With traditional farming practices, saline water results in soil salinization, rendering it unfit for raising most crop plants. Indeed, many arid and semi-arid areas were simply considered unsuitable for agriculture, and agricultural development of these areas was not systematically attempted until the second half of the 20th century.

Research in biosalinity includes studies of the biochemical and physiological mechanisms of salt tolerance in plants, breeding and selection for salt tolerance (halotolerance), discovery of periods in a crop plant's life cycle when it may be less sensitive to salt, use of saline irrigation water to increase desirable traits (such as sugar concentration in a fruit) or to control the ripening process, study of the interaction between salinity and soil properties, and development of naturally salt-tolerant plant species (halophytes) into useful agricultural crops. See also halophile bacteria, which thrive under conditions of high salinity.

Figure 4.3: ***Tetragonia tetragonioides*** **(Pallos) Kuntze.**

When properly applied (watering well in excess of evapotranspiration, maintaining soil structure for excellent drainage), brackish-water irrigation does not result in increased salinization of the soil. Sometimes this means that farmers have to add extra water after a rainstorm, to carry salts back down to below the root zone.

VI. Plant disease resistance

Plant disease resistance is crucial to the reliable production of food, and it provides significant reductions in agricultural use of fuel, land, water and other inputs. There are numerous examples of devastating plant disease impacts (Irish Potato Famine, Chestnut blight), as well as recurrent severe plant disease issues (Rice blast, Soybean cyst nematode, Citrus canker). However, disease control measures are reasonably successful for most crops. Across large regions and many crop species, it is estimated that diseases typically reduce plant yields by 10% every year in more developed settings, but yield loss to diseases often exceeds 20% in less developed settings.

Plant disease resistance derives both from pre-formed defenses and from infection-induced responses mediated by the plant immune system. Relative to a disease-susceptible plant, disease resistance is often defined as reduction of pathogen growth on or in the plant, while the term disease tolerance describes plants that exhibit less disease damage despite similar levels of pathogen growth. Disease outcome is determined by the three-way interaction of the pathogen, the plant, and the environmental conditions (an interaction known as the disease triangle). Defense-activating compounds can move cell-to-cell and systemically through the plant vascular system, but plants do not have circulating immune cells so most cell types in plants retain the capacity to express a broad suite of antimicrobial defenses. Although obvious *qualitative* differences in disease resistance can be observed when some plants are compared (allowing classification as "resistant" or "susceptible" after infection by the same pathogen strain at similar pathogen inoculum levels in similar environments), a gradation of *quantitative* differences in disease resistance is more typically observed between plant lines or genotypes. Plants are almost always resistant to certain pathogens but susceptible to other pathogens; resistance is usually pathogen species-specific or pathogen strain-specific.

Common Mechanisms of Plant Disease Resistance: Pre-formed structures and compounds that contribute to resistance

- Plant cuticle/surface
- Plant cell walls
- Antimicrobial chemicals (for example: glucosides, saponins)
- Antimicrobial proteins
- Enzyme inhibitors
- Detoxifying enzymes that break down pathogen-derived toxins
- Receptors that perceive pathogen presence and activate inducible plant defenses

Inducible plant defenses that are generated after infection

- Cell wall reinforcement (callose, lignin, suberin, cell wall proteins)
- Antimicrobial chemicals (including reactive oxygen species such as hydrogen peroxide, or peroxynitrite, or more complex phytoalexins such as genistein or camalexin)
- Antimicrobial proteins such as defensins, thionins, or PR-1
- Antimicrobial enzymes such as chitinases, beta-glucanases, or peroxidases
- Hypersensitive response - a rapid host cell death response associated with defense mediated by "Resistance genes."

VII. Plant defense against herbivory

Plant defense against herbivory or host-plant resistance (HPR) describes a range of adaptations evolved by plants which improve their survival and reproduction by reducing the impact of herbivores. Plants use several strategies to defend against damage caused by herbivores. Many plants produce secondary metabolites, known as allelochemicals, that influence the behavior, growth, or survival of herbivores. These chemical defenses can act as repellents or toxins to herbivores, or reduce plant digestibility.

Other defensive strategies used by plants include escaping or avoiding herbivores in time or in place, for example by growing in a location where plants are not easily found or accessed by herbivores, or by changing seasonal growth patterns. Another approach diverts herbivores toward eating non-essential parts, or enhances the ability of a plant to recover from the damage caused by herbivory. Some plants encourage the presence of natural enemies of herbivores, which in turn protect the plant. Each type of defense can be either *constitutive* (always present in the plant), or *induced* (produced in reaction to damage or stress caused by herbivores).

Figure 4.4: Poison ivy produces urushiol to protect the plant from herbivores. In humans this chemical produces an allergic skin rash, known as urushiol-induced contact dermatitis.

Figure 4.5: Foxgloves produce several deadly chemicals, namely cardiac and steroidal glycosides. Ingestion can cause nausea, vomiting, hallucinations, convulsions, or death.

Historically, insects have been the most significant herbivores, and the evolution of land plants is closely associated with the evolution of insects. While most plant defenses are directed against insects, other defenses have evolved that are aimed at vertebrate herbivores, such as birds and mammals. The study of plant defenses against herbivory is important, not only from an evolutionary view point, but also in the direct impact that these defenses have on agriculture, including human and livestock food sources; as beneficial 'biological control agents' in biological pest control programs; as well as the in the search for plants of medical importance.

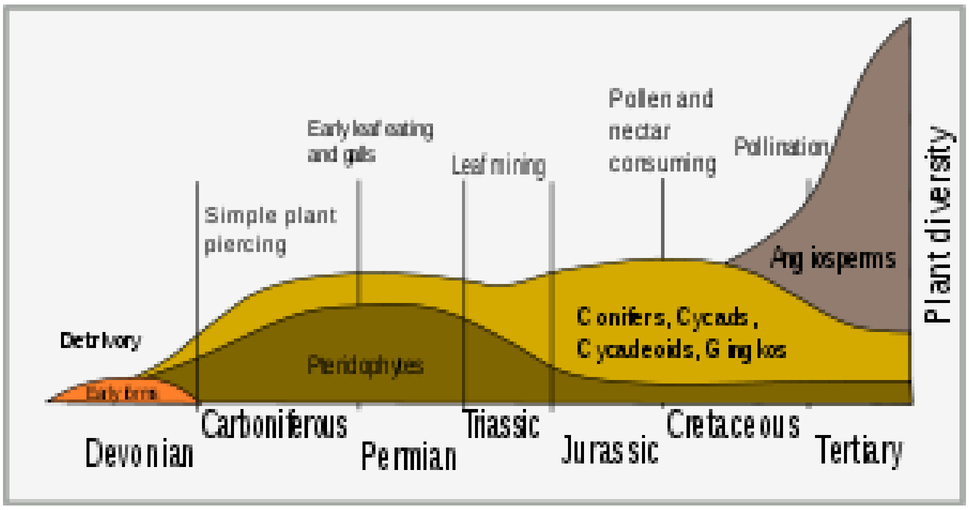

Figure 4.6: Timeline of plant evolution and the beginnings of different modes of insect herbivory.

Plant defenses can be classified generally as constitutive or induced. Constitutive defenses are always present in the plant, while induced defenses are produced or mobilized to the site where a plant is injured. There is wide variation in the composition and concentration of constitutive defenses and these range from mechanical defenses to digestibility reducers and toxins. Many external mechanical defenses and large quantitative defenses are constitutive, as they require large amounts of resources to produce and difficult to mobilize.

Induced defenses include secondary metabolic products, as well as morphological and physiological changes. An advantage of inducible, as opposed to constitutive defenses, is that they are only produced when needed, and are therefore potentially less costly, especially when herbivory is variable.

Chemical defenses

The evolution of chemical defenses in plants is linked to the emergence of chemical substances that are not involved in the essential photosynthetic and metabolic activities. These substances, secondary metabolites, are organic compounds that are not directly involved in the normal growth, development or reproduction of organisms and often produced as by-products during the synthesis of primary metabolic products. These secondary metabolites play a major role in defenses against herbivores.

Secondary metabolites are often characterized as either *qualitative* or *quantitative*. Qualitative metabolites are defined as toxins that interfere with an herbivore's metabolism, often by blocking specific biochemical reactions. Qualitative chemicals are present in plants in relatively low concentrations (often less than 2% dry weight), and are not dosage dependent. They are usually small, water soluble molecules, and therefore can be rapidly synthesized, transported and stored with relatively little energy cost to the plant. Qualitative allelochemicals are usually effective against non-adapted specialists and generalist herbivores.

Figure 4.7: Persimmon, genus *Diospyros*, has a high tannin content which gives immature fruit, seen above, an astringent and bitter flavor.

Types of chemical defenses

Plants have evolved many secondary metabolites involved in plant defense, which are collectively known as antiherbivory compounds and can be classified into three sub-groups: nitrogen compounds (including *alkaloids*, *cyanogenic glycosides* and *glucosinolates*), *terpenoids*, and *phenolics*.

Alkaloids are derived from various amino acids. Over 3000 known alkaloids exist, examples include nicotine, caffeine, morphine, colchicine, ergolines, strychnine, and quinine. Alkaloids have pharmacological effects on humans and other animals. Some alkaloids can inhibit or activate enzymes, or alter carbohydrate and fat storage by inhibiting the formation phosphodiester bonds involved in their breakdown. Certain alkaloids bind to nucleic acids and can inhibit synthesis of proteins and affect DNA repair mechanisms.

Cyanogenic glycosides are stored in inactive forms in plant vacuoles. They become toxic when herbivores eat the plant and break cell membranes allowing the glycosides to come into contact with enzymes in the cytoplasm releasing hydrogen cyanide which blocks cellular respiration. Glucosinolates are activated in much the same way as cyanogenic glucosides, and the products can cause gastroenteritis, salivation, diarrhea, and irritation of the mouth.

The terpenoids, sometimes referred to as isoprenoids, are organic chemicals similar to terpenes, derived from five-carbon isoprene units. There are over 10,000 known types of terpenoids. Most are multicyclic structures which differ from one another in both functional groups, and in basic carbon skeletons. Monoterpenoids, continuing 2 isoprene units, are volatile essential oils such as citronella, limonene, menthol, camphor, and pinene. Diterpenoids, 4 isoprene units, are widely distributed in latex and resins, and can be quite toxic.

Mechanical defenses

Figure 4.8: The thorns on the stem of this raspberry plant, serve as a mechanical defense against herbivory.

Plants have many external structural defenses that discourage herbivory. Depending on the herbivore’s physical characteristics (i.e. size and defensive armor), plant structural defenses on stems and leaves can deter, injure, or kill the grazer. Some defensive compounds are produced internally but are released onto the plant’s surface; for example, resins, lignins, silica, and wax cover the epidermis of terrestrial plants and alter the texture of the plant tissue. The leaves of holly plants, for instance, are very smooth and slippery making feeding difficult. Some plants produce gummosis or sap that traps insects.

Trees such as coconut and other palms, may protect their fruit by multiple layers of armour, needing efficient tools to break through to the seed contents, and special skills to climb the tall and relatively smooth trunk.

Thigmonasty

Thigmonastic movements, those that occur in response to touch, are used as a defense in some plants. The leaves of the sensitive plant, *Mimosa pudica*, close up rapidly in response to direct touch, vibration, or even electrical and thermal stimuli. The proximate cause of this mechanical response is an abrupt change in the turgor pressure in the pulvini at the base of leaves resulting from osmotic phenomena. This is then spread via both electrical and chemical means through the plant; only a single leaflet need be disturbed.

Figure 4.9: Coconut palms protect their fruit by surrounding it with multiple layers of armour.

Mimicry and camouflage

Some plants mimic the presence of insect eggs on their leaves, dissuading insect species from laying their eggs there. Because female butterflies are less likely to lay their eggs on plants that already have butterfly eggs, some species of neotropical vines of the genus *Passiflora* (Passion flowers) contain physical structures resembling the yellow eggs of *Heliconius* butterflies on their leaves, which discourage oviposition by butterflies.

Indirect defenses

Another category of plant defenses are those features that indirectly protect the plant by enhancing the probability of attracting the natural enemies of herbivores. Such an arrangement is known as mutualism, in this case of the "enemy of my enemy" variety.

One such feature are semiochemicals, given off by plants. Semiochemicals are a group of volatile organic compounds involved in interactions between organisms. One group of semiochemicals are allelochemicals; consisting of allomones, which play a defensive role in interspecies communication, and kairomones, which are used by members of higher trophic levels to locate food sources. When a plant is attacked it releases allelochemics containing an abnormal ratio of volatiles. Predators sense these volatiles as food cues, attracting them to the damaged plant, and to feeding herbivores. The subsequent reduction in the number of herbivores confers a fitness benefit to the plant and demonstrates the indirect defensive capabilities of semiochemicals.

Figure 4.10: The large thorn-like stipules of *Acacia collinsii* are hollow and afford shelter for ants, which in return protect the plant against herbivores.

Plants also provide housing and food items for natural enemies of herbivores, known as "biotic" defense mechanisms, as a means to maintain their presence. For example, trees from the genus *Macaranga* have adapted their thin stem walls to create ideal housing for an ant species (genus *Crematogaster*), which, in turn, protects the plant from herbivores. In addition to providing housing, the plant also provides the ant with its exclusive food source; from the food bodies produced by the plant.

Leaf shedding and colour

There have been suggestions that leaf shedding may be a response that provides protection against diseases and certain kinds of pests such as leaf miners and gall forming insects. Other responses such as the change of leaf colours prior to fall have also been suggested as adaptations that may help undermine the camouflage of herbivores. Autumn leaf color has also been suggested to act as an honest warning signal of defensive commitment towards insect pests that migrate to the trees in autumn.

Systemic acquired resistance

In plants, systemic acquired resistance (SAR) is a "whole-plant" resistance response that occurs following an earlier localized exposure to a pathogen. SAR is analogous to the innate immune system found in animals, and there is evidence that SAR in plants and innate immunity in animals may be evolutionarily conserved. SAR is important for plants to resist disease, as well as to recover from disease once formed. SAR can be induced by a wide range of pathogens, especially (but not only) those that cause tissue necrosis, and the resistance observed following induction of SAR is effective against a wide range of pathogens, which is why SAR resistance is sometimes called "broad spectrum." SAR is associated with the induction of a wide range of genes (so called PR or "pathogenesis-related" genes), and the activation of SAR requires the accumulation of endogenous salicylic acid (SA). The pathogen-induced SA signal activates a molecular signal transduction pathway that is identified by a gene called *NIM1*, *NPR1* or *SAI1* (three names for the same gene) in the model genetic system *Arabidopsis thaliana*. SAR has been observed in a wide range of flowering plants, including dicotyledon and monocotyledon species.

VIII. Hardiness (plants)

Hardiness of plants describe their ability to survive adverse growing conditions. It is usually limited to discussions of climatic adversity. Thus a plant's ability to tolerate cold, heat, drought, flooding, or wind are typically considered measurements of hardiness. Hardiness of plants is defined by their native extent's geographic location: longitude, latitude and elevation. These attributes are often simplified to a hardiness zone. In temperate latitudes, the term most often describes resistance to cold, or "cold-hardiness," and is generally measured by the lowest temperature a plant can withstand. Hardiness of a plant is usually divided into three categories: tender, half-hardy, and hardy. Tender plants are those killed by freezing temperatures, while hardy plants survive freezing—at least down to certain temperatures, depending on the plant.

Plants vary a lot in their tolerance of growing conditions. The selective breeding of varieties capable of withstanding particular climates forms an important part of agriculture and horticulture. Plants adapt to changes in climate on their own to some extent. Part of the work of nursery growers of plants consists of cold hardening, or hardening off their plants, to prepare them for likely conditions in later life.

Winter hardiness

Winter-hardy plants grow during the winter, or at least remain healthy and dormant. Apart from the obvious evergreens, these include many cultivated plants, including some cabbage and broccoli, and all kinds of carrot. Some bulbs – such as tulips – need cold winters in order to bloom, while others – such as freesia – can survive a freezing winter. Many domestic plants are assigned a hardiness zone that specifies the climates in which they can survive. Winter gardens are dependent upon the cultivation of winter-hardy plants.

IX. Heat shock protein

Heat shock proteins (HSP) are a class of functionally related proteins whose expression is increased when cells are exposed to elevated temperatures or other stress. This increase in expression is transcriptionally regulated. The dramatic upregulation of the heat shock proteins is a key part of the heat shock response and is induced primarily by heat shock factor (HSF). HSPs are found in virtually all living organisms, from bacteria to humans.

Up regulation in stress

Production of high levels of heat shock proteins can also be triggered by exposure to different kinds of environmental stress conditions, such as infection, inflammation, exercise, exposure of the cell to toxins (ethanol, arsenic, trace metals and ultraviolet light, among many others), starvation, hypoxia (oxygen deprivation), nitrogen deficiency (in plants), or water deprivation. Consequently, the heat shock proteins are also referred to as stress proteins and their upregulation is sometimes described more generally as part of the stress response.

The mechanism by which heat-shock (or other environmental stressors) activates the heat shock factor has not been determined. However, some studies suggest that an increase in damaged or abnormal proteins brings HSPs into action.

Role as chaperone

Heat shock proteins function as intra-cellular chaperones for other proteins. They play an important role in protein-protein interactions such as folding and assisting in the establishment of proper protein conformation (shape) and prevention of unwanted protein aggregation. By helping to stabilize partially unfolded proteins, HSPs aid in transporting proteins across membranes within the cell.

Cardiovascular

Heat shock proteins appear to serve a significant cardiovascular role. Hsp90, hsp84, hsp70, hsp27, hsp20, and alpha B crystallin all have been reported as having roles in the cardiovasculature. Hsp90 binds both endothelial nitric oxide synthase and soluble guanylate cyclase which in turn are involved in vascular relaxation.

Immunity

Extracellular and membrane bound heat-shock proteins, especially Hsp70 are involved in binding antigens and presenting them to the immune system.

X. Guard cell

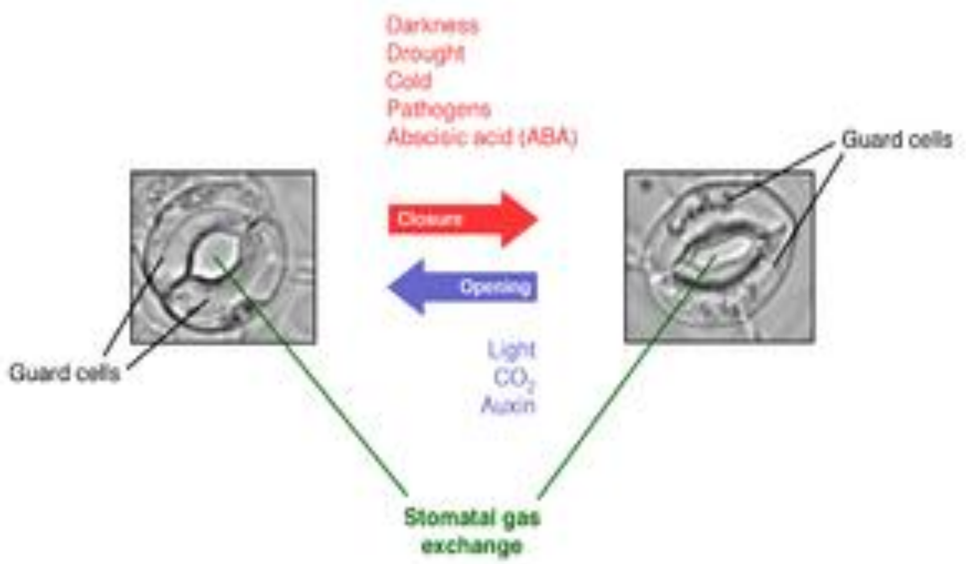

Figure 4.11: A stomatal pore in the surface (epidermis) of a leaf as viewed through a microscope. The central stomatal pore is formed by a pair of guard cells. The stomatal pore can either open (left) or close (right) depending on the environmental conditions.

Guard cells are specialized cells located in the leaf epidermis of plants. Pairs of guard cells surround tiny stomatal airway pores (Figure 4.11). These tiny holes in the surface of leaves are necessary for gas exchange into and out of the plant; carbon dioxide (CO_2) enters the plant allowing the carbon fixation reactions of photosynthesis to occur. Oxygen (O_2) exits the plant as a byproduct of photosynthesis. The opening and closing of the stomatal gas exchange holes is regulated by swelling and shrinking of the two surrounding guard cells (Figure 4.11). Due to the presence of the stomatal pores on plant leaf surfaces, water evaporates through the stomatal openings causing plants to lose water. Over 95% of water loss from plants can occur by evaporation (transpiration) through the stomatal pores. Therefore, it is important for plants to be able to balance the amount of CO_2 being brought into the plant with the amount of water escaping as a result of the open stomatal pores.

Hence, the guard cells are the gate keepers of the plants ability to take in CO_2 from the atmosphere for photosynthesis – while regulating how much water plants lose to the atmosphere. Opening and closure of the stomatal pore (Figure 4.11) is mediated by changes in the turgor pressure of the two guard cells. The turgor pressure of guard cells is controlled by movements of large quantities of ions and sugars into and out of the guard cells. When guard cells take up these solutes, the water potential (Ψ) inside the cells decreases, causing osmotic water flow into the guard cells. This leads to a turgor pressure increase causing swelling of the guard cells and the stomatal pores open (Figure 4.12). The ions that are taken up by guard cells are mainly potassium (K^+) ions and chloride (Cl^-) ions. In addition guard cells take up sugars that also contribute to opening of the stomatal pores.

Engineering Plant Water Loss and Water Use Efficiency of Plants

Water stress (drought and salt stress) is one of the major environmental problems causing severe losses in agriculture and in nature. Drought tolerance of plants is mediated by several mechanisms that work together, including stabilizing and protecting the plant from damage caused by desiccation and also controlling how much water plants loose through the stomatal pores during drought. A plant hormone, abscisic acid (ABA), is produced in response to drought. A major type of ABA receptor has been identified. Future research is needed to test if these receptors can be used to engineer drought tolerance in plants. The plant hormone ABA causes the stomatal pores to close in response to drought, which reduces plant water loss via transpiration to the atmosphere and allows plants to avoid or slow down water loss during droughts. The use of drought tolerant crop plants would lead to a reduction in crop losses during droughts. Since guard cells control water loss of plants, the investigation on how stomatal opening and closure are regulated could lead to the development of plants with improved avoidance or slowing of desiccation and better water use efficiency.

Ion Channels And Transport Proteins Mediate Ion Uptake And Release In Guard Cells

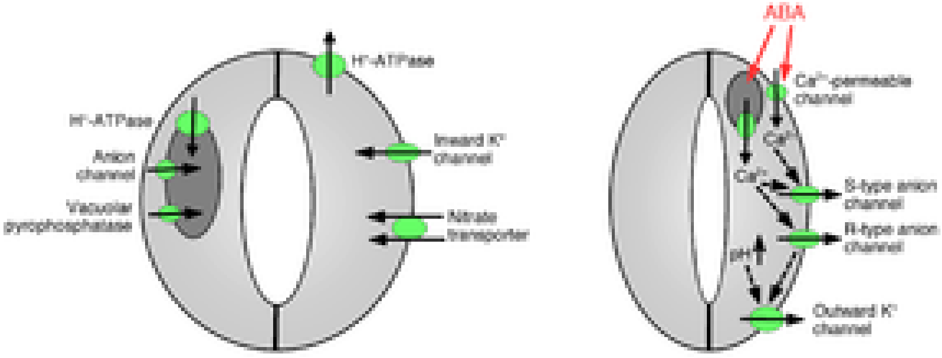

Figure 4.12: Ion channels and pumps regulating stomatal opening and closure.

Ion uptake into guard cells causes stomatal opening: The opening of gas exchange pores requires the uptake of potassium ions into guard cells. Potassium channels and pumps have been identified and shown to function in the uptake of ions and opening of stomatal apertures (Figure 4.12). Ion release from guard cells causes stomatal pore closing: Other ion channels have been identified that mediate release of ions from guard cells, which results in osmotic water efflux from guard cells due to osmosis, shrinking of the guard cells, and closing of stomatal pores (Figures 4.11 and 4.12). Specialized potassium efflux channels participate in mediating release of potassium from guard cells. Anion channels were identified as important controllers of stomatal closing. Anion channels have several major functions in controlling stomatal closing: (a) They allow release of anions, such as chloride and malate from guard cells, which is needed for stomatal closing. (b) Anion channels are activated by signals that cause stomatal closing, for example by intracellular calcium and ABA. The resulting release of negatively charged anions from guard cells results in an electrical shift of the membrane to more positive voltages (depolarization) at the intracellular surface of the guard cell plasma membrane. This electrical depolarization of guard cells leads to activation of the outward potassium channels and the release of potassium through these channels (Figure 4.12). At least two major types of anion channels have been characterized in the plasma membrane: S-type anion channels and R-type anion channels.

Vacuolar Ion Transport For Stomatal Movements

Vacuoles are large intracellular storage organelles in plants cells. In addition to the ion channels in the plasma membrane, vacuolar ion channels have important functions in regulation of stomatal opening and closure because vacuoles can occupy up to 90% of guard cell's volume. Therefore, a majority of ions are released from vacuoles when stomata are closed. Vacuolar K^+ (VK) channels and fast vacuolar channels can mediate K^+ release from vacuoles. Vacuolar K^+ (VK) channels are activated by elevation in the intracellular calcium concentration. Another type of calcium-activated channel, is the slow vacuolar (SV) channel. SV channels have been shown to function as cation channels that are permeable to Ca^{2+} ions, but their exact functions are not yet known in plants.

XI. Thermoregulation

Thermoregulation is the ability of an organism to keep its body temperature within certain boundaries, even when the surrounding temperature is very different. This process is one aspect of homeostasis: a dynamic state of stability between an animal's internal environment and its *external* environment (the study of such processes in zoology has been called ecophysiology or physiological ecology). If the body is unable to maintain a normal temperature and it increases significantly above normal, a condition known as hyperthermia occurs. This occurs when the body is exposed to constant temperatures of approximately 55° C, any prolonged exposure (longer than a few hours) at this temperature and up to around 70° C death is almost inevitable. The opposite condition, when body temperature decreases below normal levels, is known as hypothermia.

Figure 4.13: A dog panting is an example of thermoregulation.

Whereas an organism that *thermoregulates* is one that keeps its core body temperature within certain limits, a thermoconformer is subject to changes in body temperature according to changes in the temperature outside of its body. It was not until the introduction of thermometers that any exact data on the temperature of animals could be obtained. It was then found that local differences were present, since heat production and heat loss vary considerably in different parts of the body, although the circulation of the blood tends to bring about a mean temperature of the internal parts. Hence it is important to identify the parts of the body that most closely reflect the temperature of the internal organs. Also, for such results to be comparable, the measurements must be conducted under comparable conditions. The rectum has traditionally been considered to reflect most accurately the temperature of internal parts, or in some cases of sex or species, the vagina, uterus or bladder.

Thermoregulation in humans

As in other mammals, thermoregulation is an important aspect of human homeostasis. Most body heat is generated in the deep organs, especially the liver, brain, and heart, and in contraction of skeletal muscles. Humans have been able to adapt to a great diversity of climates, including hot humid and hot arid. High temperatures pose serious stresses for the human body, placing it in great danger of injury or even death. For humans, adaptation to varying climatic conditions includes both physiological mechanisms as a byproduct of evolution, and the conscious development of cultural adaptations.

There are four avenues of heat loss: convection, conduction, radiation, and evaporation. If skin temperature is greater than that of the surroundings, the body can lose heat by radiation and conduction. But if the temperature of the surroundings is greater than that of the skin, the body actually *gains* heat by radiation and conduction. In such conditions, the only means by which the body can rid itself of heat is by evaporation. So when the surrounding temperature is higher than the skin temperature, anything that prevents adequate evaporation will cause the internal body temperature to rise. During sports activities, evaporation becomes the main avenue of heat loss. Humidity affects thermoregulation by limiting sweat evaporation and thus heat loss.

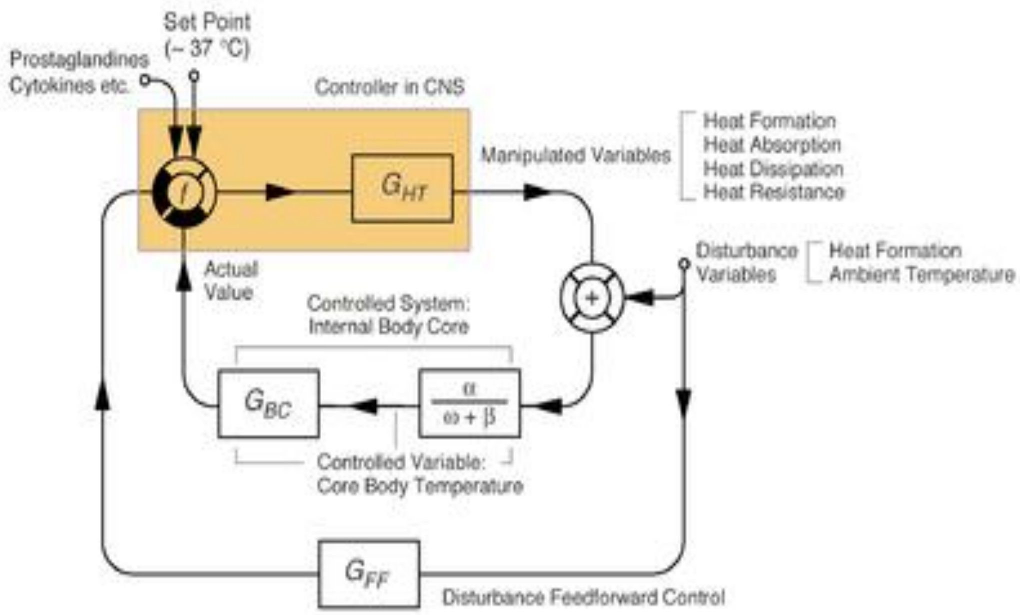

Figure 4.14: Simplified information processing structure of human thermoregulation.

The skin assists in homeostasis (keeping different aspects of the body constant e.g. temperature). It does this by reacting differently to hot and cold conditions so that the inner body temperature remains more or less constant. Vasodilation and sweating are the primary modes by which humans attempt to lose excess body heat. The brain creates much heat through the countless reactions which occur. Even the process of thought creates heat. The head has a complex system of blood vessels, which keeps the brain from overheating by bringing blood to the thin skin on the head, allowing heat to escape. The effectiveness of these methods is influenced by the character of the climate and the degree to which the individual is acclimatized.

In hot conditions

1. Sweat glands under the skin secrete sweat (a fluid containing mostly water with some dissolved ions) which travels up the sweat duct, through the sweat pore and onto the surface of the skin. This causes heat loss via evaporative cooling; however, a lot of essential water is lost.
2. The hairs on the skin lie flat, preventing heat from being trapped by the layer of still air between the hairs. This is caused by tiny muscles under the surface of the skin called erector pili muscles relaxing so that their attached hair follicles are not erect. These flat hairs increase the flow of air next to the skin increasing heat loss by convection. When environmental temperature is above core body temperature, sweating is the only physiological way for humans to lose heat.

Thermoregulation in hot and humid conditions

In general, humans appear physiologically well adapted to hot dry conditions. However, effective thermoregulation is reduced in hot, humid environments such as the Red Sea and Persian Gulf (where moderately hot summer temperatures are accompanied by unusually high vapor pressures), tropical environments, and deep mines where the atmosphere can be water-saturated. In hot-humid conditions, clothing can impede efficient evaporation. In such environments, it helps to wear light clothing such as cotton, that is pervious to sweat but impervious to radiant heat from the sun. This minimizes the gaining of radiant heat, while allowing as much evaporation to occur as the environment will allow. Clothing such as plastic fabrics that are impermeable to sweat and thus do not facilitate heat loss through evaporation, can actually contribute to heat stress.

In cold conditions

1. Sweat stops being produced.
2. The minute muscles under the surface of the skin called erector pili muscles (attached to an individual hair follicle) contract (piloerection), lifting the hair follicle upright. This makes our hairs stand on end which acts as an insulating layer, trapping heat. This is what also causes goose bumps since humans don't have very much hair and the contracted muscles can easily be seen.
3. Arterioles carrying blood to superficial capillaries under the surface of the skin can shrink (constrict), thereby rerouting blood away from the skin and towards the

warmer core of the body. This prevents blood from losing heat to the surroundings and also prevents the core temperature dropping further. This process is called vasoconstriction. It is impossible to prevent all heat loss from the blood, only to reduce it. In extremely cold conditions excessive vasoconstriction leads to numbness and pale skin. Frostbite only occurs when water within the cells begins to freeze, this destroys the cell causing damage.

4. Muscles can also receive messages from the thermo-regulatory center of the brain (the hypothalamus) to cause shivering. This increases heat production as respiration is an exothermic reaction in muscle cells. Shivering is more effective than exercise at producing heat because the animal remains still. This means that less heat is lost to the environment via convection. There are two types of shivering: low intensity and high intensity.
5. Mitochondria can convert fat directly into heat energy, increasing the temperature of all cells in the body. Brown fat is specialized for this purpose, and is abundant in newborns and animals that hibernate.
6. The process explained above, in which the skin regulates body temperature is a part of thermoregulation. This is one aspect of homeostasis-the process by which the body regulates itself to keep internal conditions constant.

Temperature symptoms

Hypothermia**,** Hyperthermia**,** Heat stroke**,** Raynaud's phenomenon (Raynaud's disease)**,** Induced hypothermia**,** Erythromelalgia (hyperthermia)

Thermoregulation in vertebrates

By numerous observations upon humans and other animals, John Hunter showed that the essential difference between the so-called warm-blooded and cold-blooded animals lies in observed constancy of the temperature of the former, and the observed variability of the temperature of the latter. Almost all birds and mammals have a high temperature almost constant and independent of that of the surrounding air (homeothermy). Almost all other animals display a variation of body temperature, dependent on their surroundings (poikilothermy).

Figure 4.15: Seeking shade is one method of cooling. Here Sooty Tern chicks are using a Black-footed Albatross chick for shade.

Certain mammals are exceptions to this rule, being warm-blooded during the summer or daytime, but cold-blooded during the winter when they hibernate or at night during sleep. J. O. Wakelin Barratt has demonstrated that under certain pathological conditions, a warm-blooded (homeothermic) animal may become temporarily cold-blooded (poikilothermic). He has shown conclusively that this condition exists in rabbits suffering from rabies during the last period of their life, the rectal temperature being then within a few degrees of the room temperature and varying with it. He explains this condition by the assumption that the nervous mechanism of heat regulation has become paralysed. The respiration and heart-rate being also retarded during this period, the resemblance to the condition of hibernation is considerable. Again, Sutherland Simpson has shown that during deep anaesthesia a warm-blooded animal tends to take the same temperature as that of its environment.

Brain control

Thermoregulation in both ectotherms and endotherms is controlled mainly by the preoptic area of the anterior hypothalamus. Such homeostatic control is separate from the sensation of temperature.

Ectotherms

Ectothermic cooling

- ❖ Vaporization:
- Getting wet in a river, lake or sea.
- ❖ Convection:

- Climbing to lower ground from trees, into valleys, burrows, etc.
- Entering a cold water or air current.
- Building a nest that allows natural or generated air/water flow for cooling.

❖ Conduction:

- Lying on cold ground.
- Staying wet in a river, lake or sea.
- Covering in cool mud.

❖ Radiation:

- Finding shade.
- Entering a burrow shaped for radiating heat (Black-box effect).
- Expanding folds of skin.
- Exposing wing surfaces.

Ectothermic heating (or minimizing heat loss)

❖ Convection:

- Climbing to higher ground up trees, ridges, rocks.
- Entering a warm water or air current.
- Building an insulated nest or burrow.

❖ Conduction:

- Lie on hot rock.

❖ Radiation:

- Lie in sun.
- Fold skin to reduce exposure.
- Conceal wing surfaces.

❖ Insulation

- Change shape to alter surface/volume ratio
- Inflate the body

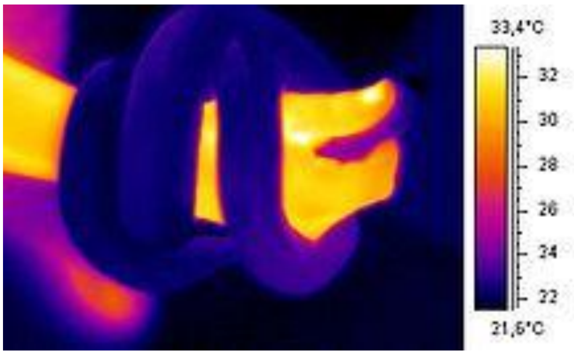

Figure 4.16: Thermographic image of a snake around an arm.

To cope with low temperatures, some fish have developed the ability to remain functional even when the water temperature is below freezing; some use natural antifreeze or antifreeze proteins to resist ice crystal formation in their tissues. Amphibians and reptiles cope with heat loss by evaporative cooling and behavioral adaptations.

Endotherms

An endotherm is an animal that regulates its own body temperature, typically by keeping it a constant level. To regulate body temperature, an organism may need to prevent heat gains in arid environments. Evaporation of water, either across respiratory surfaces or across the skin in those animals possessing sweat glands, helps in cooling body temperature to within the organism's tolerance range. Animals with a body covered by fur have limited ability to sweat, relying heavily on panting to increase evaporation of water across the moist surfaces of the lungs and the tongue and mouth. Birds also avoid overheating by gular fluttering, flapping the wings near the gular (throat) skin, similar to panting in mammals, since their thin skin has no sweat glands. Down feathers trap warm air acting as excellent insulators just as hair in mammals acts as a good insulator. Mammalian skin is much thicker than that of birds and often has a continuous layer of insulating fat beneath the dermis — in marine mammals such as whales this is called blubber. Dense coats found in desert endotherms also aid in preventing heat gain.

A cold weather strategy is to temporarily decrease metabolic rate, decreasing the temperature difference between the animal and the air and thereby minimizing heat loss. Furthermore, having a lower metabolic rate is less energetically expensive. Many animals survive cold frosty nights through torpor, a short-term temporary drop in body temperature. Organisms when presented with the problem of regulating body temperature have not only behavioural, physiological and structural adaptations, but also a feedback system to trigger these adaptations to regulate temperature accordingly. The main features of this system are *stimulus, receptor, modulator, effector* and then the feedback of the newly adjusted temperature to the *stimulus.* This cyclical process aids in homeostasis.

Thermoregulation in birds and mammals

In cold environments, birds and mammals employ the following adaptations and strategies to minimize heat loss.

1. Using small smooth muscles (erector pili in mammals) which are attached to feather or hair shafts; this non-shivering thermogenesis distorts the surface of the skin as the feather/hair shaft is made more erect (called goose bumps or pimples)
2. Increasing body size to more easily maintain core body temperature (warm-blooded animals in cold climates tend to be larger than similar species in warmer climates (see Bergmann's Rule))
3. Having the ability to store energy as fat for metabolism
4. Have shortened extremities
5. Have countercurrent blood flow in extremities - this is where the warm arterial blood travelling to the limb passes the cooler venous blood from the limb and heat is exchanged warming the venous blood and cooling the arterial (e.g. Arctic Wolf or penguins.

Figure 4.17: Kangaroo licking its arms to cool down on a very hot day.

In warm environments, birds and mammals employ the following adaptations and strategies to maximize heat loss.

1. Behavioral adaptations like living in burrows during the day and being nocturnal.
2. Evaporative cooling by perspiration and panting.
3. Storing fat reserves in one place (e.g. camel's hump) to avoid its insulating effect.
4. Elongated, often vascularized extremities to conduct body heat to the air.

Thermoregulation in plants

Thermogenesis occurs in the flowers of many plants in the Araceae family as well as in cycad cones. In addition, some plants in the Alum family - such as the Eastern Skunk Cabbage, the Philodendron (*Philodendron selloum*), and the Sacred lotus (*Nelumbo nucifera*) are able to thermoregulate themselves, remaining on average 20 °C (36 °F) above air temperature while flowering. Heat is produced by breaking down the starch that was stored in their roots, which requires the consumption of oxygen at a rate approaching that of a flying hummingbird.

Behavioural temperature regulation

Animals other than humans regulate and maintain their body temperature with physiological adjustments and behavior. Desert lizards are ectotherms and so unable to metabolically control their temperature but can do this by altering their location. They may do this by in the morning only raising their head from its burrow and then exposing their entire body. By basking in the sun, the lizard absorbs solar heat. It may also absorb heat by conduction from heated rocks that have stored radiant solar energy. To lower their temperature, lizards may seek cooler objects with which to contact, find shade or return to their burrow. They also go to their burrows to avoid cooling when the sun goes down or the temperature falls.

Animals also engage in kleptothermy in which they share or even steal each other's body warmth. In endotherms such as bats and birds (such as the mousebird and emperor penguin it allows the sharing of body heat (particularly amongst juveniles). This allows the individuals to increase their thermal inertia (as with gigantothermy) and so reduce heat loss. Some ectotherms share burrows of ectotherms. Other animals exploit termite mounds.

Some animals living in cold environments maintain their body temperature by preventing heat loss. Their fur grows more densely to increase the amount of insulation. Some animals are regionally heterothermic and are able to allow their less insulated extremities to cool to temperatures much lower than their core temperature—nearly to 0 °C. This minimizes heat loss through less insulated body parts, like the legs, feet (or hooves), and nose.

Hibernation, estivation, and daily torpor

To cope with limited food resources and low temperatures, some mammals hibernate in underground burrows. In order to remain in "stasis" for long periods, these animals must build up brown fat reserves and be capable of slowing all body functions. True hibernators (e.g. groundhogs) keep their body temperature down throughout their hibernation while the core temperature of false hibernators (e.g. bears) varies with them sometimes emerging from their dens for brief periods. Some bats are true hibernators which rely upon a rapid, non-shivering thermogenesis of their brown fat deposit to bring them out of hibernation.

Estivation occurs in summer (like siestas) and allows some mammals to survive periods of high temperature and little water (e.g. turtles burrow in pond mud).

XII. Oxygen toxicity

Oxygen toxicity is a condition resulting from the harmful effects of breathing molecular oxygen (O_2) at elevated partial pressures. It is also known as oxygen toxicity syndrome, oxygen intoxication, and oxygen poisoning. Historically, the central nervous system condition was called the Paul Bert effect, and the pulmonary condition the Lorrain Smith effect, after the researchers who pioneered its discovery and description in the late 19th century. Severe cases can result in cell damage and death, with effects most often seen in the central nervous system, lungs and eyes. Oxygen toxicity is a concern for scuba divers, those on high concentrations of supplemental oxygen (particularly premature babies), and those undergoing hyperbaric oxygen therapy.

The result of breathing elevated concentrations of oxygen is hyperoxia, an excess of oxygen in body tissues. The body is affected in different ways depending on the type of exposure. Central nervous system toxicity is caused by short exposure to high concentrations of oxygen at greater than atmospheric pressure. Pulmonary and ocular toxicity result from longer exposure to elevated oxygen levels at normal pressure. Symptoms may include disorientation, breathing problems, and vision changes such as myopia. Prolonged or very high oxygen concentrations can cause oxidative damage to cell membranes, the collapse of the alveoli in the lungs, retinal detachment, and seizures. Oxygen toxicity is managed by reducing the exposure to elevated oxygen levels. Studies show that, in the long term, a robust recovery from most types of oxygen toxicity is possible.

Classification

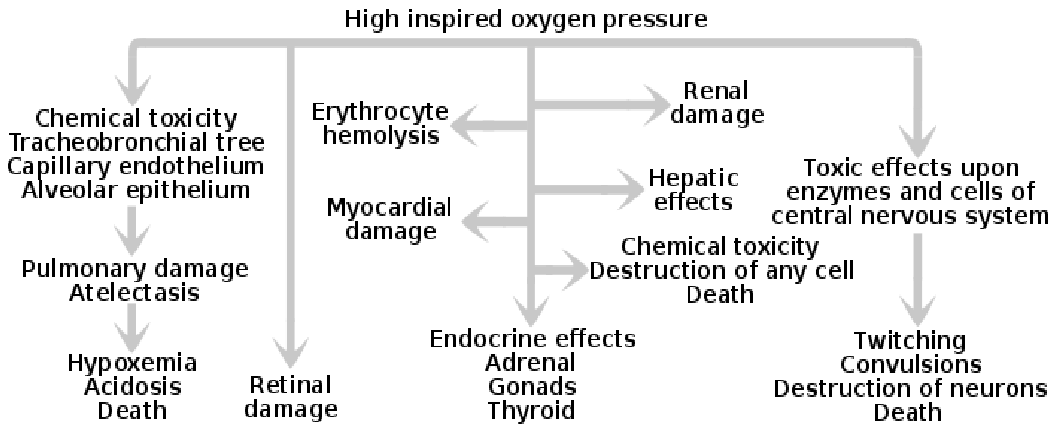

Figure 4.18: The effects of oxygen toxicity may be classified by the organs affected, producing three principal forms.

1. Central nervous system, characterised by convulsions followed by unconsciousness, occurring under hyperbaric conditions;
2. Pulmonary (lungs), characterised by difficulty in breathing and pain within the chest, occurring when breathing elevated pressures of oxygen for extended periods;
3. Ocular (retinopathic conditions), characterised by alterations to the eyes, occurring when breathing elevated pressures of oxygen for extended periods.

Central nervous system oxygen toxicity can cause seizures, brief periods of rigidity followed by convulsions and unconsciousness, and is of concern to divers who encounter greater than atmospheric pressures. Pulmonary oxygen toxicity results in damage to the lungs, causing pain and difficulty in breathing. Oxidative damage to the eye may lead to myopia or partial detachment of the retina. Pulmonary and ocular damage are most likely to occur when supplemental oxygen is administered as part of a treatment, particularly to newborn infants, but are also a concern during hyperbaric oxygen therapy.

Oxidative damage may occur in any cell in the body but the effects on the three most susceptible organs will be the primary concern. It may also be implicated in red blood cell destruction (hemolysis), damage to liver (hepatic), heart (myocardial), endocrine glands (adrenal, gonads, and thyroid), or kidneys (renal), and general damage to cells.

Causes

Oxygen toxicity is caused by exposure to oxygen at partial pressures greater than those to which the body is normally exposed. This occurs in three principal settings: underwater diving, hyperbaric oxygen therapy and the provision of supplemental oxygen, particularly to premature infants. In each case, the risk factors are markedly different.

Table 4.1: Oxygen Poisoning at 90 ft (27 m) in the Dry in 36 Subjects in Order of Performance – K W Donald.

Exposure (mins.)	Num. of Subjects	Symptoms
96	1	Prolonged dazzle; severe spasmodic vomiting
60–69	3	Severe lip-twitching; Euphoria; Nausea and vertigo; arm twitch
50–55	4	Severe lip-twitching; Dazzle; Blubbering of lips; fell asleep; Dazed
31–35	4	Nausea, vertigo, lip-twitching; Convulsed
21–30	6	Convulsed; Drowsiness; Severe lip-twitching; epigastric aura; twitch L arm; amnesia
16–20	8	Convulsed; Vertigo and severe lip twitching; epigastric aura; spasmodic respiration;
11–15	4	Inspiratory predominance; lip-twitching and syncope; Nausea and confusion
6–10	6	Dazed and lip-twitching; paraesthesiae; vertigo; "Diaphragmatic spasm"; Severe nausea

Central nervous system toxicity

Exposures, from minutes to a few hours, to partial pressures of oxygen above 1.6 bars (160 kPa)—about eight times the atmospheric concentration—are usually associated with central nervous system oxygen toxicity and are most likely to occur among patients undergoing hyperbaric oxygen therapy and divers. Since atmospheric pressure is about 1 bar (100 kPa), central nervous system toxicity can only occur under hyperbaric conditions, where ambient pressure is above normal. Divers breathing air at depths greater than 60 m (200 ft) face an increasing risk of an oxygen toxicity "hit" (seizure). Divers breathing a gas mixture enriched with oxygen, such as nitrox, can similarly suffer a seizure at shallower depths, should they descend below the maximum depth allowed for the mixture.

Pulmonary toxicity

The lungs, as well as the remainder of the respiratory tract, are exposed to the highest concentration of oxygen in the human body and are therefore the first organs to show toxicity. Pulmonary toxicity occurs with exposure to concentrations of oxygen greater than 0.5 bar (50 kPa), corresponding to an oxygen fraction of 50% at normal atmospheric pressure. Signs of pulmonary toxicity begins with evidence of tracheobronchitis, or inflammation of the upper airways, after an asymptomatic period between 4 and 22 hours at greater than 95% oxygen, with some studies suggesting symptoms usually begin after approximately 14 hours at this level of oxygen.

Ocular toxicity

Prolonged exposure to high inspired fractions of oxygen causes damage to the retina. Damage to the developing eye of infants exposed to high oxygen fraction at normal pressure has a different mechanism and effect from the eye damage experienced by adult divers under hyperbaric conditions. Hyperoxia may be a contributing factor for the disorder called retrolental fibroplasia or retinopathy of prematurity (ROP) in infants. In preterm infants, the retina is often not fully vascularised. Retinopathy of prematurity occurs when the development of the retinal vasculature is arrested and then proceeds abnormally. Associated with the growth of these new vessels is fibrous tissue (scar tissue) that may contract to cause retinal detachment. Supplemental oxygen exposure, while a risk factor, is not the main risk factor for development of this disease. Restricting supplemental oxygen use does not necessarily reduce the rate of retinopathy of prematurity, and may raise the risk of hypoxia-related systemic complications.

CONTINENTAL DRIFT AND PLATE TECTONICS

Ecologists understanding of geography have changed by a new paradigm that has rise geology that of plate tectonics and sea level spreading. The continental masses of the land together with the continental shelves are to be thought of as plates of rock 700 kilogram thick. These continental plates are nudged along by motions of the sea floor so that the continents drift on a scale of evolutionary time.

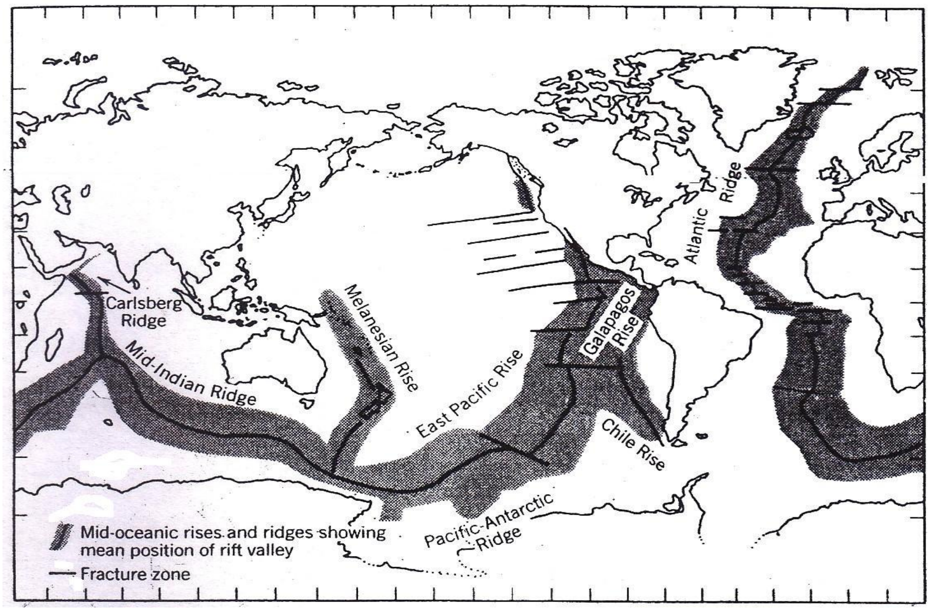

Figure 4.19: Mid Ocean rises and ridges. The rises and ridges are where new crustal rock is formed. Continents are moved away from theridges.

Where the continents drift away from each other there is a tear in the earth's crust, along the length of which hot rocks pour to fill the gap and form the lines of the mid-ocean ridges (Figure 4.19). Where the sliding plates collide there is the buckling of a mountain range as one plate slithers under the other. The line of a plunging plate (SUBDUCTION) yields a deep ocean trench on the side of it. As the descending plate is driven down, rocks melt and a line of volcanos marks its passing.

This general conception of plate tectonics is best described as a PARADIGM of science because it became important when the evidence for it was piled up to so visible a mass that virtually all geologists suddenly found it to be true (Cox, 1973; Kuhn, 1962). Plate tectonics explained so many' things at once: the abyssal trenches; the island arcs of volcanos; the fitting shapes of distant continents; the lines of mountain-building or OROGENY; the high heat flux along the mid-ocean ridges; the intense magnetization of these ridges resulting from the rapid cooling of their lava in seawater; the long TRANSFORM FAULTS like the San Andreas.

The geological literature now provides us with a series of maps of the globe at different periods in the past (Figure 4.20). The maps are made on the assumption that each continental plate remains intact, unless there is evidence to the contraband the relative position of each plate is plotted from data on the direction of the earth's magnetic field recorded in ancient rocks. The age of each orientation is obtained by radiometric dating of the same rocks used for paleomagnetic determinations.

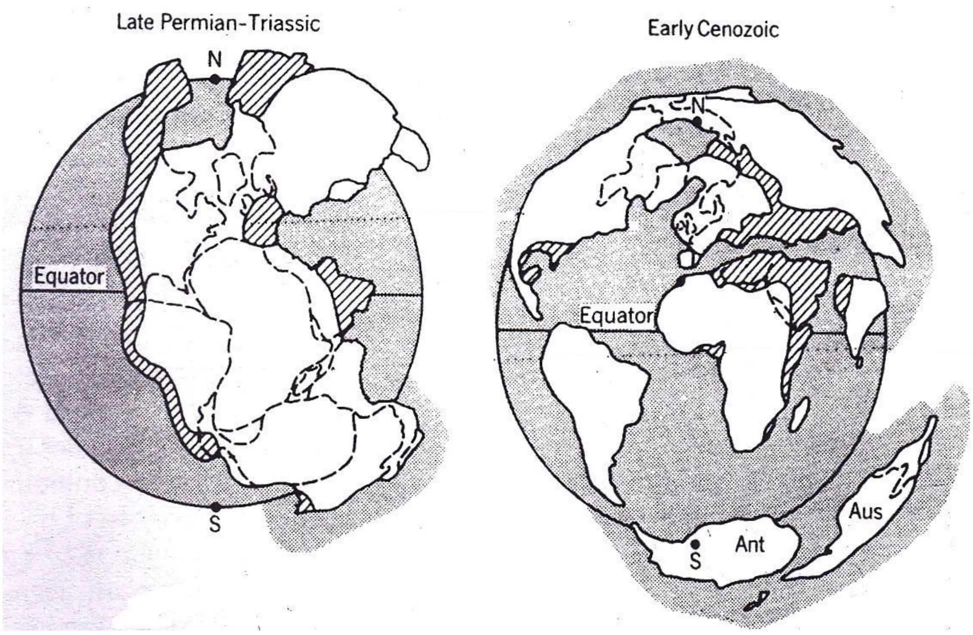

Figure 4.20: Continental drift-Data for biogeography. Relative positions of the continents at two stages in the earth's history

These maps are now raw material for bio-geographers who can seek to explain modern patterns of distribution as, in part, resulting from the transport of ancestors on drifting continents. But formerly the evidence of biogeography itself was prime evidence on which a theory of continental drift could be built, and the possibilities of continental drift were as much a subject of biogeography as of geology.

Wegener (1912, 1966) first put forward the theory of continental drift because he saw that the shapes of Africa and South America were so complementary that they could be fitted together to make a super-continent He found some evidence that the two were once joined by matching rocks from either coast, but even more in the works of biogeographers who could not explain DISJUNCT DISTRIBUTIONS of species without postulating LAND BRIDGES across which ancestral populations once crossed. Most celebrated of the *land bridges* constructed on this logic was GONDWANALAND, the supposed bridge that connected Australia with South America via Antarctica. Gondwanaland seemed necessary to explain the otherwise puzzling occurrence of marsupials in Australia and South America but nowhere else in the-world. Proponents of the land bridge said that this had sunk beneath the sea before placental mammals evolved in the Old World so that no placentals reached Australia. For Wegener, Gondwanaland was the old super-continent that had split in the middle before placental time, after which the parts drifted away.

Biogeographers argued over the validity of continental drift and land bridges for more than half a century. Was it *parsimonious* to move large parts of the crust of the earth in order to get a fossil from one continent to another? Or was it more reasonable to postulate natural rafts for large animals and carriage in storms for small? Some land bridges were eminently believable, like the isthmus of Panama or a connection between England and France when sea level fell in an ice age, but the movements of continents across great oceans were not so easy to conceive. Darwin himself had rebuked persons who made land bridges as easily as a cook makes pancakes.

Undoubtedly a biogeographer should try to find a way in which animals might have crossed the sea rather than expect land and animal to have crossed the ocean together. A sea crossing, for instance, certainly is required to get all the ancestors of the endemic fauna of the Galapagos Islands from South America, since modern geology of the sea floor shows conclusively that these islands never were joined to the mainland. The animals certainly rafted to the Galapagos, and rafts of flotsam can be seen today coming down the great Guayas river of Ecuador and heading out to sea in the general direction of the Galapagos. But some biogeographers once thought a Galapagos land bridge as likely as Gondwanaland.

A major work of biogeography was published just before the final triumph of continental drift to show that all the known facts of zoogeography could be explained without any drifting at all (Darlington, 1957). But once the theory of continental drift rested on geological data, rather than requiring a whole continent to be boat to a fossil, Darlington (1965) announced he had become a drifter, "but not an extreme one. His position is the proper one for a biologist: if geological evidence shows that continents have moved, then continental drift is the likely explanation for disjunct distributions but the argument should not be driven the other way to say that because the animals moved the continents must have moved also. Maps like those of Figure 4.20 now describe for ecologists the changing sets of the theater in which the evolutionary play of dispersion and speciation is performed (Hutchinson, 1965).

Summary: The shifting community and ecosystem stage

Recognizable communities and ecosystems exist because the surface of the earth is divided into different physical patches. The largest disjunctions of all are between land and sea, but even these are not permanent as the continents drift across evolutionary time. The next separate patches are set by climate, stemping a pattern that we recognize in our largest community the great plant formations, or biomes. Whether biomes are separate or blended depends on whether their controlling climates are separate or blended.

The permanence of biomes depends on the permanence of climate, and this is subject to frequent change. As recently as 10,000 years ago all the climates of the earth were displaced, or actually were different, as the-globe emerged from the climatic upheaval of the last ice age. Equivalent changes of climate have been recurrent throughout at least the last two million years. It follows that biomes have been made and remade repeatedly, suggesting that communal relationships are in almost perpetual flux.

Communities and ecosystems are built as species enter or are removed from habitats defined by landscape and shifting climate. Communities are inherently subject to change. Ecologists often quote Hutchinson's (1965) aphorism about the ecological theater and the evolutionary play, saying that ecosystems set the stage for speciation. And yet for community studies,' ecology contributes much of the play as well as the theater. Communities are shifting alliances of species, constantly being altered as physical habitats alter: If perpetual change forces the endless individual changes of evolution, change also drives continual alteration of communities made of shifting combinations of existing species.

CHAPTER- V

ENDEMISM, ENDANGERED SPECIES AND HOTSPOTS

Endemism is the ecological state of being unique to a defined geographic location, such as an island, nation or other defined zone, or habitat type, and found only there; organisms that are indigenous to a place are not endemic to it if they are also found elsewhere. For example, all species of lemur are endemic to the island of Madagascar; none are found elsewhere. The extreme opposite of endemism is cosmopolitan distribution.

Figure 4.21: The Orange-breasted Sunbird (*Nectarinia violacea*) is exclusively found in Fynbos vegetation.

Physical, climatic, and biological factors can contribute to endemism. The Orange-breasted Sunbird is exclusively found in the Fynbos vegetation zone of southwestern South Africa. Political factors can play a part if a species is protected, or actively hunted, in one jurisdiction but not another.

There are two subcategories of endemism - paleoendemism and neoendemism. Paleoendemism refers to a species that was formerly widespread but is now restricted to a smaller area. Neoendemism refers to a species that has recently arisen such as a species that has diverged and become reproductively isolated, or one that has formed following hybridization and is now classified as a separate species. This is a common process in plants, especially those which exhibit polyploidy.

Endemic types or species are especially likely to develop on biologically isolated areas such as islands because of their geographical isolation. This includes remote island groups, such as Hawaii, the Galápagos Islands, and Socotra, and biologically isolated but not island areas such as the highlands of Ethiopia, or large bodies of water like Lake Baikal.

Endemics can easily become endangered or extinct if their restricted habitat changes, particularly but not only due to the actions of man, including the introduction of new organisms. There were millions of both Bermuda Petrels and "Bermuda cedars" (actually *junipers*) in Bermuda when it was settled at the start of the seventeenth century. By the end of the century the petrels were thought to be extinct. Cedars, already ravaged by centuries of shipbuilding, were driven nearly to extinction in the twentieth century by the introduction of a parasite. Bermuda petrels and cedars, although not actually extinct, are very rare today, as are other species endemic to Bermuda.

Ecoregions with high endemism

According to the World Wildlife Fund, the following ecoregions have the highest percentage of endemic plants.

1. Fynbos (South Africa)
2. Hawaiian tropical dry forests (United States)
3. Hawaiian tropical rainforests (United States)
4. Kwongan heathlands (Australia)
5. Madagascar dry deciduous forests (Madagascar)
6. Madagascar lowland forests (Madagascar)
7. New Caledonia dry forests (New Caledonia)
8. New Caledonia rain forests (New Caledonia)
9. Sierra Madre de Oaxaca pine-oak forests (Mexico)
10. Sierra Madre del Sur pine-oak forests (Guatemala)
11. Luzon montane rainforests (Philippines)
12. Luzon rainforests (Philippines)
13. Luzon tropical pine forests (Philippines)
14. Mindanao montane rain forests (Philippines)
15. Mindanao-Eastern Visayas rain forests (Philippines)
16. Palawan rain forests (Philippines)

Centres of endemism

A Centre of Endemism is an area in which the ranges of restricted-range species overlap, or a localised area which has a high occurrence of endemics. Centres of endemism may overlap with biodiversity hotspots which are biogeographic regions characterized both by high levels of plant endemism *and by serious levels of habitat loss*. The exact delineation of centres of endemism is difficult and some overlap with one another. Centres of endemism are high conservation priority areas.

Examples of Centres of Endemism

Tanzania

A local centre of endemism is focussed on an area of lowland forests around the plateaux inland of Lindi in SE Tanzania, with between 40 and 91 species of vascular plants which are not found elseware.

South Africa

At least 19 centres of plant endemism including:

- The Soutpansberg Centre of Plant Endemism
- The Maputaland Centre of Plant Endemism
- The Hantam–Roggeveld Centre of Plant Endemism
- The Drakensberg Alpine Centre
- Kaokoveld Centre of Endemism
- The Cape Floristic Region
- The Pondoland Centre of Plant Endemism

Endemic animals and birds are species that are found only locally and are found no where else in the world. The endemism of Indian biodiversity is highly determined primarily in the North-East, Western Ghats, North-West Himalaya and the Andaman and Nicobar islands.

Of the 49,219 plant species, 5150 are endemic and distributed into 141 genera under 47 families corresponding to about 30% of the world's recorded flora, which means 30% of the world's recorded flora is endemic to India. Of these endemic species, 3,500 are found in the Himalayas and adjoining regions and 1600 in the Western Ghats alone. About 62% of the known amphibian species are endemic with the majority occurring in the Western Ghats. Nearly 50% of the lizards of India are endemic with a high degree of endemicity in the Western Ghats. There are 42 species of Endemic birds in India out of which 35 are found in Western ghats.

IUCN Categories

Figure 4.22.

1. **Extinct**: Examples: Javan Tiger, Thylacine, Dodo, Passenger Pigeon, Caribbean Monk Seal, Dimetrodon, Aurochs, Dusky Seaside Sparrow. Philippine Eagle (the last remaining member of the species has died, or is presumed beyond reasonable doubt to have died).
2. **Extinct in the wild**: captive individuals survive, but there is no free-living, natural population. Examples: Alagoas Curassow
3. **Critically endangered**: faces an extremely high risk of extinction in the immediate future. Examples: Mountain Gorilla, Arakan Forest Turtle, Darwin's Fox, Javan Rhino, Brazilian Merganser, Gharial, Vaquita
4. **Endangered**: faces a very high risk of extinction in the near future. Examples: Dhole, Blue Whale, Bonobo, Ethiopian wolf, Giant Panda, Snow Leopard, African Wild Dog, Tiger, Indian Rhinoceros, three species of Albatrosses, Crowned Solitary Eagle, Philippine Eagle, Markhor, Orangutan, Grevy's zebra, Tasmanian Devil,
5. **Vulnerable**: faces a high risk of extinction in the medium-term. Examples: Cheetah, Gaur, Lion, Sloth Bear, Manatee, Polar Bear, African Golden Cat, Komodo dragon, Golden hamster
6. **Conservation dependent**: The following animals are not severely threatened, but must depend on conservation programs. Examples: Spotted Hyena, Blanford's fox, Leopard Shark, Black Caiman, Killer whale
7. **Near threatened**: may be considered threatened in the near future. Examples: Blue-billed Duck, Solitary Eagle, Small-clawed Otter, Maned Wolf, Tiger Shark, Okapi
8. **Least concern**: no immediate threat to the survival of the species. Examples: Nootka Cypress, Wood Pigeon, White-tailed Mongoose, House Mouse, Wolverine

IUCN Red List – Threatened species

The IUCN Red List of Threatened Species (also known as the IUCN Red List or Red Data List), founded in 1963, is the world's most comprehensive inventory of the global conservation status of plant and animal species. The International Union for Conservation of Nature (IUCN) is the world's main authority on the conservation status of species. A series of Regional Red Lists are produced by countries or organizations, which assess the risk of extinction to species within a political management unit.

The IUCN Red List is set upon precise criteria to evaluate the extinction risk of thousands of species and subspecies. These criteria are relevant to all species and all regions of the world. The aim is to convey the urgency of conservation issues to the public and policy makers, as well as help the international community to try to reduce species extinction. Major species assessors include BirdLife International, the Institute of Zoology (the research division of the Zoological Society of London), the World Conservation Monitoring Centre, and many Specialist Groups within the IUCN Species Survival Commission (SSC). Collectively, assessments by these organizations and groups account for nearly half the species on the Red List.

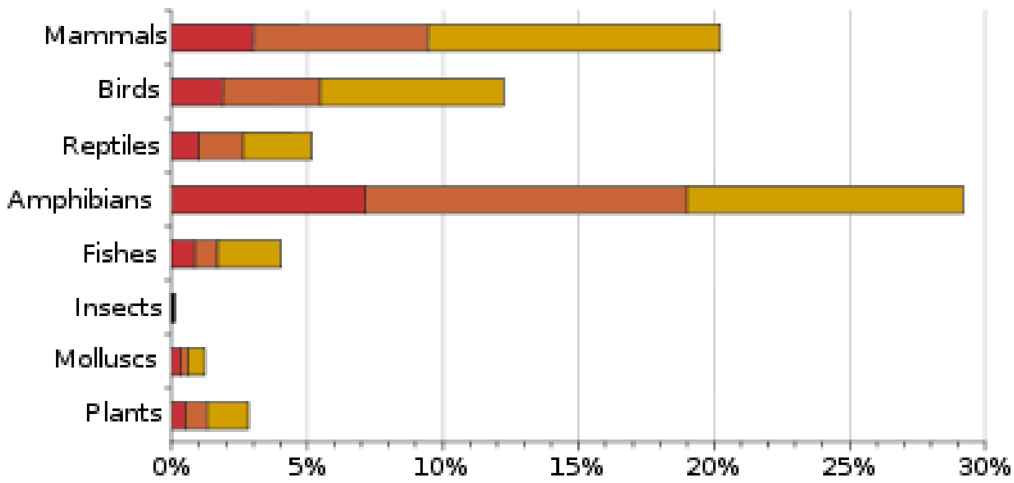

Figure 4.23

The IUCN aims to have the category of every species re-evaluated every 5 years if possible, or at least every ten years. This is done in a peer reviewed manner through IUCN Species Survival Commission (SSC) Specialist Groups, which are Red List

Authorities responsible for a species, group of species or specific geographic area, or in the case of BirdLife International, an entire class (Aves).

IUCN Red List Endangered species

IUCN Red List refers to a specific category of threatened species, and may include critically endangered species. *IUCN Red List of Threatened Species* uses the term *endangered species* as a specific category of imperilment, rather than as a general term. Under the IUCN Categories and Criteria, *endangered species* is between *critically endangered* and *vulnerable*. Also *critically endangered* species may also be counted as *endangered species* and fill all the criteria**.** The more general term used by the IUCN for species at risk of extinction is *threatened species*, which also includes the less-at-risk category of vulnerable species together with endangered and critically endangered. IUCN categories include.

An endangered species is a population of organisms which is at risk of becoming extinct because it is either few in numbers, or threatened by changing environmental or predation parameters. The International Union for Conservation of Nature (IUCN) has calculated the percentage of endangered species as 40 percent of all organisms based on the sample of species that have been evaluated through 2006. Many nations have laws offering protection to conservation reliant species: for example, forbidding hunting, restricting land development or creating preserves.

Only a few of the many species at risk of extinction actually make it to the lists and obtain legal protection like Pandas. Many more species become extinct, or potentially will become extinct, without gaining public notice.

Figure 4.24: The Siberian Tiger is a subspecies of tiger that is critically endangered; three subspecies of tiger are already extinct.

Causes of Endangerment

When discussing the causes of endangerment, it is important to understand that individual species are not the only factors involved in this dilemma. Endangerment is a broad issue, one that involves the habitats and environments where species live and interact with one another. Although some measures are being taken to help specific cases of endangerment, the universal problem cannot be solved until humans protect the natural environments where endangered species dwell.

There are many reasons why a particular species may become endangered. Although these factors can be analyzed and grouped, there are many causes that appear repeatedly. Below are several factors leading to endangerment.

Habitat Destruction

Our planet is continually changing, causing habitats to be altered and modified. Natural changes tend to occur at a gradual pace, usually causing only a slight impact on individual species. However, when changes occur at a fast pace, there is little or no time for individual species to react and adjust to new circumstances. This can create disastrous results, and for this reason, rapid habitat loss is the primary cause of species endangerment. The strongest forces in rapid habitat loss are human beings. Nearly every region of the earth has been affected by human activity, particularly during this past century. The loss of microbes in soils that formerly supported tropical forests, the extinction of fish and various aquatic species in polluted habitats, and changes in global climate brought about by the release of greenhouse gases are all results of human activity.

Figure 4.25: The most endangered asiatic top predator, the dhole is on the edge of extinction.

It can be difficult for an individual to recognize the effects that humans have had on specific species. It is hard to identify or predict human effects on individual species and habitats, especially during a human lifetime. But it is quite apparent that human activity has greatly contributed to species endangerment. For example, although tropical forests may look as though they are lush, they are actually highly susceptible to destruction. This is because the soils in which they grow are lacking in nutrients. It may take Centuries to re-grow a forest that was cut down by humans or destroyed by fire, and many of the world's severely threatened animals and plants live in these forests. If the current rate of forest loss continues, huge quantities of plant and animal species will disappear.

Introduction of Exotic Species

Native species are those plants and animals that are part of a specific geographic area, and have ordinarily been a part of that particular biological landscape for a lengthy period of time. They are well adapted to their local environment and are accustomed to the presence of other native species within the same general habitat. Exotic species, however, are interlopers. These species are introduced into new environments by way of human activities, either intentionally or accidentally. These interlopers are viewed by the native species as foreign elements. They may cause no obvious problems and may eventual be considered as natural as any native species in the habitat. However, exotic species may also seriously disrupt delicate ecological balances and may produce a plethora of unintended yet harmful consequences.

The worst of these unintended yet harmful consequences arise when introduced exotic species put native species in jeopardy by preying on them. This can alter the natural habitat and can cause a greater competition for food. Species have been biologically introduced to environments all over the world, and the most destructive effects have occurred on islands. Introduced insects, rats, pigs, cats, and other foreign species have actually caused the endangerment and extinction of hundreds of species during the past five centuries. Exotic species are certainly a factor leading to endangerment.

Overexploitation

A species that faces overexploitation is one that may become severely endangered or even extinct due to the rate in which the species is being used. Unrestricted whaling during the 20th century is an example of overexploitation, and the whaling industry brought many species of whales to extremely low population sizes. When several whale species were nearly extinct, a number of nations (including the United States) agreed to abide by an international moratorium on whaling. Due to this moratorium, some whale species, such as the grey whale, have made remarkable comebacks, while others remain threatened or endangered.

Due to the trade in animal parts, many species continue to suffer high rates of exploitation. Even today, there are demands for items such as rhino horns and tiger bones in several areas of Asia. It is here that there exists a strong market for traditional medicines made from these animal parts.

More Factors

Disease, pollution, and limited distribution are more factors that threaten various plant and animal species. If a species does not have the natural genetic protection against particular pathogens, an introduced disease can have severe effects on that specie. For example, rabies and canine distemper viruses are presently destroying carnivore populations in East Africa. Domestic animals often transmit the diseases that affect wild populations, demonstrating again how human activities lie at the root of most causes of endangerment. Pollution has seriously affected multiple terrestrial and aquatic species, and limited distributions are frequently a consequence of other threats; populations confined to few small areas due to of habitat loss, for example, may be disastrously affected by random factors.

Conservation status (By risk of extinction)

❖ **Extinct**
- Extinct
- Extinct in the Wild

❖ **Threatened**
- Critically Endangered
- Endangered
- Vulnerable

❖ **At lower risk**
- Conservation Dependent
- Near Threatened

- Least Concern

The conservation status of a species is an indicator of the likelihood of that endangered species not living. Many factors are taken into account when assessing the conservation status of a species; not simply the number remaining, but the overall increase or decrease in the population over time, breeding success rates, known threats, and so on.

Internationally, 199 countries have signed an accord agreeing to create Biodiversity Action Plans to protect endangered and other threatened species. In the United States this plan is usually called a species Recovery Plan.

Nature Serve Conservation Status

Nature Serve and its member programs and collaborators use a suite of factors to assess the conservation status of plant, animal, and fungal species, as well as ecological communities and systems. These assessments lead to the designation of a conservation status rank. For species these ranks provide an estimate of extinction risk, while for ecological communities and systems they provide an estimate of the risk of elimination. Conservation status ranks for ecological systems in North America are currently under development.

Conservation status ranks are based on a one to five scale, ranging from critically imperiled (G1) to demonstrably secure (G5). Status is assessed and documented at three distinct geographic scales-global (G), national (N), and state/province (S). The numbers have the following meaning.

- 1 = critically imperiled
- 2 = imperiled
- 3 = vulnerable
- 4 = apparently secure
- 5 = secure

For example, G1 would indicate that a species is critically imperiled across its entire range (i.e., globally). In this sense the species as a whole is regarded as being at very high risk of extinction. A rank of S3 would indicate the species is vulnerable and at moderate risk within a particular state or province, even though it may be more secure elsewhere.

Species and ecosystems are designated with either an "X" (presumed extinct or extirpated) if there is no expectation that they still survive, or an "H" (possibly extinct or extirpated) if they are known only from historical records but there is a chance they may still exist. Other variants and qualifiers are used to add information or indicate any range of uncertainty. See the following conservation status rank definitions for complete descriptions of ranks and qualifiers.

Why Save Endangered Species?

Plants and animals hold medicinal, agricultural, ecological, commercial and aesthetic/recreational value. Endangered species must be protected and saved so that future generations can experience their presence and value.

Medicinal

Plants and animals are responsible for a variety of useful medications. In fact, about forty percent of all prescriptions written today are composed from the natural compounds of different species. These species not only save lives, but they contribute to a prospering pharmaceutical industry worth over $40 billion annually. Unfortunately, only 5% of known plant species have been screened for their medicinal values, although we continue to lose up to 100 species daily.

The Pacific yew, a slow-growing tree found in the ancient forests of the Pacific Northwest, was historically considered a "trash" tree (it was burned after clearcutting). However, a substance in its bark taxol was recently identified as one of the most promising treatments for ovarian and breast cancer.

Additionally, more than 3 million American heart disease sufferers would perish within 72 hours of a heart attack without digitalis, a drug derived from the purple foxglove.

Agricultural

There are an estimated 80,000 edible plants in the world. Humans depend upon only 20 species of these plants, such as wheat and corn, to provide 90% of the world's food. Wild relatives of these common crops contain essential disease-resistant material. They also provide humans with the means to develop new crops that can grow in inadequate lands such as in poor soils or drought-stricken areas to help solve the world hunger problem. In the 1970s, genetic material from a wild corn species in Mexico was used to stop a leaf fungus that had previously wiped out 15% of the U.S. corn crop.

Ecological

Plant and animal species are the foundation of healthy ecosystems. Humans depend on ecosystems such as coastal estuaries, prairie grasslands, and ancient forests to purify their air, clean their water, and supply them with food. When species become endangered, it is an indicator that the health of these vital ecosystems is beginning to unravel. The U.S. Fish and Wildlife Service estimates that losing one plant species can trigger the loss of up to 30 other insect, plant and higher animal species.

The northern spotted owl, listed as threatened in 1990, is an indicator of the declining health of the ancient forests of the Pacific Northwest. These forests are the home to over 100 other old-growth dependent species, which are at risk due to decades of unsustainable forest management practices.

Pollution off the coast of Florida is killing the coral reefs along the Florida Keys, which serve as habitat for hundreds of species of fish. Commercial fish species have begun to decline, causing a threat to the multi-million dollar tourism industry, which depends on the quality of the environment.

Commercial

Various wild species are commercially raised, directly contributing to local and regional economies. Commercial and recreational salmon fishing in the Pacific Northwest provides 60,000 jobs and $1 billion annually in personal income, and is the center of Pacific Northwest Native American culture. This industry and way of life, however, is in trouble as salmon decline due to habitat degradation from dams, clearcutting, and overgrazing along streams.

Freshwater mussels which are harvested, cut into beads, and used to stimulate pearl construction in oysters form the basis of a thriving industry which supports approximately 10,000 U.S. jobs and contributes over $700 million to the U.S.

economy annually. Unfortunately, 43% of the freshwater mussel species in North America are currently endangered or extinct.

Aesthetic/Recreational

Plant and animal species and their ecosystems form the basis of America's multi-billion dollar, job-intensive tourism industry. They also supply recreational, spiritual, and quality-of-life values as well.

Each year over 108 million people in the United States participate in wildlife-related recreation including observing, feeding, and photographing wildlife. Americans spend over $59 billion annually on travel, lodging, equipment, and food to engage in non-consumptive wildlife recreation. Our national heritage of biological diversity is an invaluable and irreplaceable resource. Our quality of life and that of future generations depends on our preservation of plant and animal species.

Ways You Can Help Endangered Species

1. Conserve Habitats

- One of the most important ways to help threatened plants and animals survive is to protect their habitats permanently in national parks, nature reserves or wilderness areas. There they can live without too much interference from humans. It is also important to protect habitats outside reserves such as on farms and along roadsides.
- You can visit a nearby national park or nature reserve. Some national parks have special guided tours and walks for kids. Talk to the rangers to find out whether there are any threatened species and how they are being protected. You and your friends might be able to help the rangers in their conservation work.
- When you visit a national park, make sure you obey the wildlife code: follow fire regulations; leave your pets at home; leave flowers, birds' eggs, logs and bush rocks where you find them; put your rubbish in a bin or, better still, take it home.
- If you have friends who live on farms, encourage them to keep patches of bush as wildlife habitats and to leave old trees standing, especially those with hollows suitable for nesting animals.
- Some areas have groups which look after local lands and nature reserves. They do this by removing weeds and planting local native species in their place. You could

join one of these groups, or even start a new one with your parents and friends. Ask your local parks authority or council for information.

- By removing rubbish and weeds and replanting with natives you will allow the native bush to gradually regenerate. This will also encourage native animals to return.

2. Make Space For Our Wildlife

- Build a birdfeeder and establish a birdbath for the neighborhood birds.
- Plant a tree and build a birdhouse in your backyard.
- Start composting in your backyard garden or on your balcony. It eliminates the need for chemical fertilizers which are harmful to animals and humans, and it benefits your plants!

3. Recycle, Reduce, And Reuse

- Encourage your family to take public transportation. Walk or ride bicycles rather than using the car.
- Save energy by turning off lights, radios and the TV when you are not using them.
- Turn off the tap while you brush your teeth and use water-saving devices on your toilet, taps and showerhead.
- Ask your parents to buy products and food without packaging whenever possible. Take your own bag to the store. It will reduce the amount of garbage and waste your family produces.
- Recycle your toys, books and games by donating them to a hospital, daycare, nursery school or children's charity.

4. Encourage your family to shop for organic fruits and vegetables.

Plant Native Plants That Are Local to the Area. If you can, plant native plants instead of non-native or introduced ones in your garden. You don’t want seeds from introduced plants escaping into the bush. Native grasses, flowers, shrubs and trees are more likely to attract native birds, butterflies and other insects, and maybe even some threatened species.

5. Control Introduced Plants and Animals

- Non-native plants and animals are ones that come from outside your local area.

- Some parks and reserves, beaches, bush-land and rivers are now infested with invasive plants, and native species often cannot compete with these plants.
- Many environmental weeds come from people's gardens.
- Sometimes, the seeds are taken into the bush by the wind or by birds.
- Controlling these foreign species is an important step in protecting wildlife

Protection Law Summaries

There are several laws that have been adopted to regulate the import, export, and sale of wildlife. There are also laws that protect species from various forms of inhumane treatment, including capturing and killing. The following summaries were taken from the US Fish & Wildlife Service, Division of Law Enforcement.

Bald and Golden Eagle Protection Act (16 U.S.C. 668-668C)

This Act makes it illegal to import, export, or take bald or golden eagles, or to sell, purchase, or barter their parts, or products made from them, including their nests or eggs.

Migratory Bird Treaty Act (16 U.S.C. 703-712)

Except as allowed by implementing regulations, this Act makes it unlawful to pursue, hunt, kill, capture, possess, buy, sell, purchase, or barter any migratory bird, including the feathers or other parts, nests, eggs, or migratory bird products.

Lacey Act (18 U.S.C. 42; 16 U.S.C. 3371-3378)

This Act provides authority to the Secretary of the Interior to designate injurious wildlife and ensure the humane treatment of wildlife shipped to the United States. Further, it prohibits the importation, exportation, transportation, sale, or purchase of fish and wildlife taken or possessed in violation of State, Federal, Indian tribal, and foreign laws. The Amendments strengthen and improve the enforcement of Federal wildlife laws and improve Federal assistance to the States and foreign governments in the enforcement of their wildlife laws. Also, the act provides an important tool in the effort to gain control of smuggling and trade in illegally taken fish and wildlife.

Marine Mammal Protection Act (16 U.S.C. 1361-1407)

This Act establishes a moratorium on the taking and importation of marine mammals, including parts and products, and defines Federal responsibility for conservation of marine mammals, with management authority vested in the Department of the Interior for the sea otter, walrus, polar bear, dugong, and manatee.

Airborne Hunting Act (16 U.S.C. 742j-1)

Section 13 of the Fish and Wildlife Act of 1956 is commonly referred to as the Airborne Hunting Act, or Shooting From Aircraft Act, and prohibits taking or harassing wildlife from aircraft, except when protecting wildlife, livestock, and human health or safety, as authorized by a Federal- or State-issued license or permit.

National Wildlife Refuge System Administration Act of 1966 (16 U.S.C. 668dd-668ee)

This Act constitutes an "Organic Act" for the National Wildlife Refuge System by providing guidelines and directives for administration and management of all areas in the system including "wildlife refuges, areas for the protection and conservation of fish and wildlife that are threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas."

Endangered Species Act (16 U.S.C. 1531-1543)

This Act prohibits the importation, exportation, taking, and commercialization in interstate or foreign commerce of fish and wildlife, and plants that are listed as threatened or endangered species. The Act also implements the provisions of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Antarctic Conservation Act (16 U.S.C. 2401)

The purpose of the Act is to provide for the conservation and protection of the fauna and flora of Antarctica and of the ecosystem upon which such fauna and flora depend. The primary prohibitions of the Act make it unlawful for any United States citizen to take any native bird or mammal in Antarctica or to collect any native plant from any specially protected area within Antarctica. In addition, the Act makes it unlawful for any United States citizen or any foreign person in the United States to possess, sell, offer for sale, deliver, receive, carry, transport, import, export, or attempt to import or export from the United States any native mammal or bird taken in Antarctica or any plant collected in any specially protected area.

African Elephant Conservation Act (16 U.S.C. 4201-4245)

The purpose of the Act is to provide additional protection for the African elephant. The Act establishes an assistance program to elephant producing countries of Africa and provides for the establishment of an African Elephant Conservation Fund. In addition, the Act places a moratorium on the importation of raw or worked ivory from African elephant producing countries that do not meet certain criteria found in the Act.

Wild Bird Conservation Act of 1992 (16 U.S.C. 4901)

The act promotes the conservation of exotic birds by encouraging wild bird conservation and management programs in countries of origin; by ensuring that all trade in such species involving the United States is biologically sustainable and to the benefit of the species; and by limiting or prohibiting imports of exotic birds when necessary to ensure that exotic wild populations are not harmed by removal for the trade.

Facts about Endangered Species

- According to scientists, more than one and one-half million species exist on the earth today. However, recent estimates state that at least 20 times that many species inhabit the planet.
- In the United States, 735 species of plants and 496 species of animals are listed as threatened or endangered.
- 266 of these listed species have recovery plans currently under development.
- There are more than 1,000 animal species endangered worldwide.
- There are more than 3,500 protected areas in existence worldwide. These areas include parks, wildlife refuges and other reserves. They cover a total of nearly 2 million square miles (5 million square km), or 3% of our total land area.
- Aquatic species, which are often overlooked, are facing serious trouble. One third of the United States' fish species, two-thirds of its crayfish species, and almost three-quarters of its mussel species are in trouble.

WWF

For more than 45 years, WWF has been protecting the future of nature. The world's leading conservation organization, WWF works in 100 countries and is supported by 1.2 million members in the United States and close to 5 million globally. WWF's unique way of working combines global reach with a foundation in science, involves action at every level from local to global, and ensures the delivery of innovative solutions that meet the needs of both people and nature.

IUCN

The IUCN supports scientific research, manages field projects all over the world and brings governments, non-government organizations, United Nations agencies, companies and local communities together to develop and implement policy, laws and best practice. IUCN is the world's oldest and largest global environmental network - a democratic membership union with more than 1,000 government and NGO member organizations, and almost 11,000 volunteer scientists in more than 160 countries. IUCN's work is supported by more than 1,000 professional staff in 60 offices and hundreds of partners in public, NGO and private sectors around the world. The Union's headquarters are located in Gland, near Geneva, Switzerla.

List of endangered species in India

The following list includes all animals and birds which occur in India and are rated as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) in the 2004 International Union for Conservation of Nature and Natural Resources (*IUCN*) and Wildlife Institute of India*(WII)*. Most of these animals and birds are the most protected things in India conservation reliant species.

Critically Endangered

- Jenkin's Shrew (*Crocidura jenkensii*). (Endemic to India.)
- Ganges Shark(*Glyphis gangeticus*)(Endemic to India.)
- Himalayan Wolf (*Canis himalayensis*) (Endemic to India and Nepal.)
- Indian Vulture (*Gyps indicus*)
- Malabar Large-spotted Civet (*Viverra civettina*).
- Namdapha Flying Squirrel (*Biswamayopterus biswasi*). (Endemic to India.)
- Pygmy Hog (Sus salvanius).
- Salim Ali's Fruit Bat (*Latidens salimalii*). (Endemic to India.)
- Wroughton's Free-tailed Bat (*Otomops wroughtoni*). (Endemic to India.)
- Jerdon's Courser (*Rhinoptilus bitorquatus*). (Endemic to India)

Endangered

- Andaman Shrew (*Crocidura andamanensis*). (Endemic to India)
- Andaman Spiny Shrew (*Crocidura hispida*). (Endemic to India)
- Asian Arowana (*Scleropages formosus*
- Asiatic Black Bear (*Selenarctos thibetanus*)
- Asiatic Lion (*Panthera leo persica*)
- Asiatic Wild Dog/ Dhole (*Cuon alpinus*)
- Banteng (*Bos javanicus*)
- Blue Whale (*Balaenoptera musculus*)
- Capped Leaf Monkey (*Trachypithecus pileatus*)
- Chiru (Tibetan Antelope) (*Pantholops hodgsonii*)
- Wild Cat (*Felis silvestris ornata*)
- Fin Whale (*Balaenoptera physalus*)
- Ganges River Dolphin (*Platanista gangetica gangetica*)
- Golden Leaf Monkey (*Trachypithecus geei*)
- Great Indian Rhinoceros (*Rhinoceros unicornis*)
- Hispid Hare (*Caprolagus hispidus*)
- Hoolock Gibbon (*Bunipithecus hoolock*) (Previously Hylobates hoolock).
- Indian Elephant or Asian Elephant (*Elephas maximus*)
- Indus River Dolphin (*Platanista minor*).
- Kashmir Stag/ Hangul (*Cervus elaphus hanglu*)
- Kondana Soft-furred Rat (*Millardia kondana*). (Endemic to India).
- Lion-tailed Macaque (*Macaca silenus*). (Endemic to India).
- Loggerhead Sea Turtle (*Caretta caretta*).
- Malabar Civet (*Viverra civettina*)
- Markhor (*Capra falconeri*).
- Marsh Mongoose (*Herpestes palustris*). (Endemic to India.) (Previously considered to be a subspecies of *Herpestes javanicus*).
- Narcondam Hornbill (“Rhyticeros narcondami”)
- Nicobar Shrew (*Crocidura nicobarica*). (Endemic to India).
- Nicobar Tree Shrew (*Tupaia nicobarica*). (Endemic to India).
- Nilgiri Leaf Monkey (*Presbytis johni*)
- Nilgiri Tahr (*Hemitragus hylocrius*). (Endemic to India).
- Olive Ridley Turtle. (Endemic to Orissa, Andhra Pradesh, India)

- Particolored Flying Squirrel (*Hylopetes alboniger*).
- Peter's Tube-nosed Bat (*Murina grisea*). (Endemic to India).
- Pygmy Hog (*Sus salvanius*)
- Red Panda (Lesser Panda) (*Ailurus fulgens*).
- Royal Bengal Tiger (*Panthera tigris tigris*).
- Sei Whale (*Balaenoptera borealis*).
- Servant Mouse (*Mus famulus*). (Endemic to India).
- Snow Leopard (*Uncia uncia*).
- Wild Water Buffalo (*Bubalus bubalis*). (Previously *Bubalus arnee*).
- Woolly Flying Squirrel (*Eupetaurus cinereus*).

Vulnerable

- Andaman Horseshoe Bat (*Rhinolophus cognatus*). (Endemic to India.)
- Andaman Rat (*Rattus stoicus*). (Endemic to India.)
- Argali (*Ovis ammon*).
- Himalayan W-toothed Shrew (*Crocidura attenuate*)
- Sri Lankan Highland Shrew (*Suncus montanus*).
- Asiatic Black Bear (*Ursus thibetanus*).
- Asiatic Golden Cat (*Catopuma temminckii*).
- Assamese Macaque (*Macaca assamensis*).
- Back-striped Weasel (*Mustela strigidorsa*).
- Barasingha (*Cervus duvauceli*).
- Bare-bellied Hedgehog (*Hemiechinus nudiventris*). (Endemic to India.)
- Blackbuck (*Antilope cervicapra*).
- Brow-antlered Deer (*Cervus eldi eldi*)
- Brown Bear (*Ursus arctos*)
- Brown fish owl (*Ketupa zeylonensis*). (Endemic to India.)
- Brown Palm Civet (*Paradoxurus jerdoni*)
- Central Kashmir Vole (*Alticola montosa*). (Endemic to India.)
- Clouded Leopard (*Neofelis nebulosa*).
- Day's Shrew (*Suncus dayi*). (Endemic to India.)
- Dhole (*Cuon alpines*).
- Dugong (*Dugong dugon*).
- Eld's Deer (*Cervus eldi*).

- Elvira Rat (*Cremnomys Elvira*). (Endemic to India.)
- European Otter(also known as Eurasian Otter) (*Lutra lutra*)
- Fishing Cat (*Prionailurus viverrinus*).
- Four-horned Antelope (*Tetracerus quadricornis*).
- Ganges River Dolphin (*Platanista gangetica*)
- Gaur (*Bos gaurus*).
- Golden Jackal (*Canis aureus*)
- Goral (*Nemorhaedus goral*)
- Himalayan Musk Deer (*Moschus chrysogaster*)
- Himalayan Shrew (*Soriculus nigrescens*)
- Himalayan Tahr (*Hemitragus jemlahicus*).
- Humpback Whale (*Megaptera novaeangliae*).
- Indian Fox (*Vulpes bengalensis*)
- Indian Giant Squirrel (*Ratufa indica*). (Endemic to India.)
- Indian Wolf (*Canis lupus indica*)
- Irrawaddy Squirrel (*Callosciurus pygerythrus*).
- Jerdon's Palm Civet (*Paradoxurus jerdoni*). (Endemic to India.)
- Kashmir Cave Bat (*Myotis longipes*).
- Kerala Rat (*Rattus ranjiniae*). (Endemic to India.)
- Khajuria's Leaf-nosed Bat (*Hipposideros durgadasi*). (Endemic to India.)
- Kolar Leaf-nosed Bat (*Hipposideros hypophyllus*). (Endemic to India.)
- Lesser Horseshoe Bat (*Rhinolophus hipposideros*).
- Lesser Panda (*Ailurus fulgens*)
- Mainland Serow (*Capricornis sumatraensis*).
- Malayan Porcupine (*Hystrix brachyuran*).
- Mandelli's Mouse-eared Bat (*Myotis sicarius*).
- Marbled Cat (*Pardofelis marmorata*).
- Mouflon (or Urial) (*Ovis orientalis*).
- Nicobar Flying Fox (*Pteropus faunulus*). (Endemic to India.)
- Nilgiri Leaf Monkey (*Trachypithecus johnii*). (Endemic to India.)
- Nilgiri Marten (*Martes gwatkinsii*). (Endemic to India.)
- Nonsense Rat (*Rattus burrus*). (Endemic to India.)
- Asiatic Wild Ass (*Equus hemionus*).
- Pale Grey Shrew (*Crocidura pergrisea*). (Endemic to India.)

- Palm Rat (*Rattus palmarum*). (Endemic to India.)
- Red Goral (*Naemorhedus baileyi*).
- Rock Eagle-owl (*Bubo bengalensis*). (Endemic to India.)
- Rusty-spotted Cat (*Prionailurus rubiginosus*).
- Sikkim Rat (*Rattus sikkimensis*).
- Sloth Bear (*Melursus ursinus*).
- Slow Loris (*Loris tardigradus*).
- Smooth-coated Otter (*Lutrogale perspicillata*). (Previously Lutra perspicillata.)
- Sperm Whale (*Physeter macrocephalus*).
- Sri Lankan Giant Squirrel (*Ratufa macroura*).
- Stumptail Macaque (*Macaca arctoides*).
- Takin (*Budorcas taxicolor*).
- Wild Goat (*Capra aegagrus*).
- Wild Yak (*Bos grunniens*).
- tiger

Threatened

- Indian Wild Ass (*Equus hemionus khur*)
- Leopard (*Panthera pardus*)
- Red Fox (*Vulpes vulpes montana*)
- kashmiri stag (*sahil and manav*)

HOTSPOTS

A biodiversity hotspot is a biogeographic region with a significant reservoir of biodiversity that is under threat from humans. The concept of biodiversity hotspots was originated by Norman Myers in two articles in "The Environmentalist" (1988 & 1990), revised after thorough analysis by Myers and others in "Hotspots: Earth's biologically Richest and Most Endangered Terrestrial Ecoregions".

To qualify as a biodiversity hotspot on Myers 2000 edition of the hotspot-map, a region must meet two strict criteria: it must contain at least 0.5% or 1,500 species of vascular plants as endemics, and it has to have lost at least 70% of its primary vegetation. Around the world, at least 25 areas qualify under this definition, with nine others possible candidates. These sites support nearly 60% of the world's plant, bird, mammal, reptile, and amphibian species, with a very high share of endemic species.

The biodiversity hotspots by region

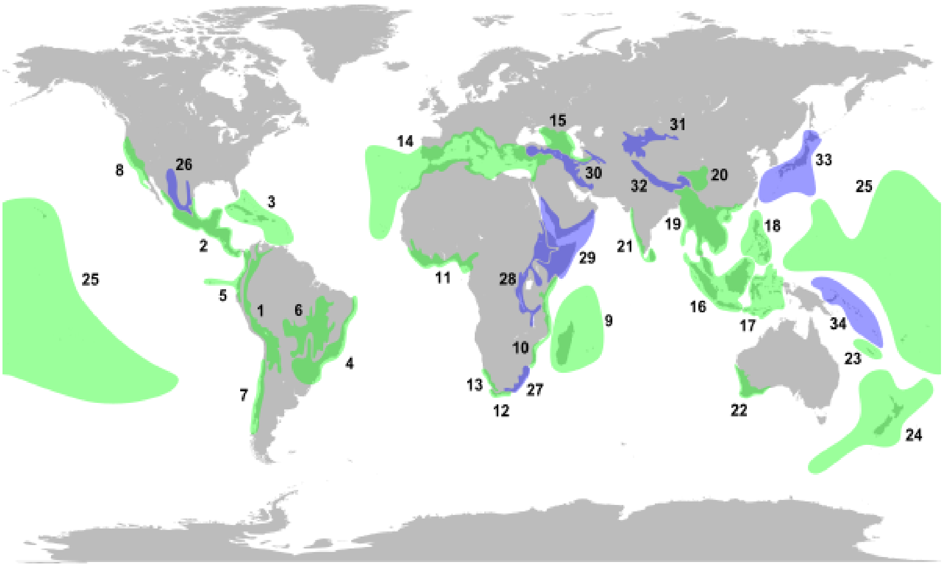

Figure 4.26: Biodiversity Hotspots by region.

North and Central America

- California Floristic Province
- Caribbean Islands
- Madrean pine-oak woodlands
- Mesoamerica

South America

- Atlantic Forest
- Cerrado
- Chilean Winter Rainfall-Valdivian Forests
- Tumbes-Chocó-Magdalena
- Tropical Andes

Europe and Central Asia

- Caucasus
- Irano-Anatolian
- Mediterranean Basin
- Mountains of Central Asia

Africa

- Cape Floristic Region
- Coastal Forests of Eastern Africa

- Eastern Afromontane
- Guinean Forests of West Africa
- Horn of Africa
- Madagascar and the Indian Ocean Islands
- Maputaland-Pondoland-Albany
- Succulent Karoo

Asia-Pacific

- East Melanesian Islands
- Eastern Himalaya
- Indo-Burma
- Japan
- Mountains of Southwest China
- New Caledonia
- New Zealand
- Philippines
- Polynesia-Micronesia
- Southwest Australia
- Sundaland
- Wallacea
- Western Ghats and Sri Lanka

Biodiversity hotspots

The Western Ghats

The Western Ghats are a chain of hills that run along the western edge of peninsular India. Their proximity to the ocean and through orographic effect, they receive high rainfall. These regions have moist deciduous forest and rain forest. The region shows high species diversity as well as high levels of endemism. Nearly 77% of the amphibians and 62% of the reptile species found here are found nowhere else. The region shows biogeographical affinities to the Malayan region, and the Satpura hypothesis proposed by Sunder Lal Hora suggests that the hill chains of Central India may have once formed a connection with the forests of northeastern India and into the Indo-Malayan region. Hora used torrent stream fishes to support the theory, but it was also suggested to hold for birds. Later studies have suggested that Hora's original model species were a demonstration of convergent evolution rather than speciation by isolation.

More recent phylogeographic studies have attempted to study the problem using molecular approaches. There are also differences in taxa which are dependent on time of divergence and geological history. Along with Sri Lanka this region also shows some faunal similarities with the Madagascan region especially in the reptiles and amphibians. Examples include the *Sibynophis* snakes, the Purple frog and Sri Lankan lizard genus *Nessia* which appears similar to the Madagascan genus *Acontias*. Numerous floral links to the Madagascan region also exist. An alternate hypothesis that these taxa may have originally evolved out-of-India has also been suggested.

Biogeographical quirks exist with some taxa of Malayan origin occurring in Sri Lanka but absent in the Western Ghats. These include insects groups such as the zoraptera and plants such as those of the genus *Nepenthes*.

The Eastern Himalayas

Figure 4.27: The Indian Rhinoceros is one of the 45 species of globally threatened mammals found in the Eastern Himalayas.

The Eastern Himalayas is the region encompassing Bhutan, northeastern India, and southern, central, and eastern Nepal. The region is geologically young and shows high altitudinal variation. It has nearly 163 globally threatened species including the One-horned Rhinoceros (*Rhinoceros unicornis*), the Wild Asian Water buffalo (*Bubalus bubalis (Arnee)*) and in all 45 mammals, 50 birds, 17 reptiles, 12 amphibians, 3 invertebrate and 36 plant species. The Relict Dragonfly (*Epiophlebia laidlawi*) is an endangered species found here with the only other species in the genus being found in Japan. The region is also home to the Himalayan Newt (*Tylototriton verrucosus*), the only salamander species found within Indian limits.

Figure 4.28: Map showing major hotspots in India.

Indo-Burma

Extinct and fossil forms

During the early Tertiary period, the Indian tableland, what is today peninsular India, was a large island. Prior to becoming an island it was connected to the African region. During the tertiary period this island was separated from the Asian mainland by a shallow sea. The Himalayan region and the greater part of Tibet lay under this sea. The movement of the Indian subcontinent into the Asian landmass created the great Himalayan ranges and raised the sea bed into what is today the plains of northern India.

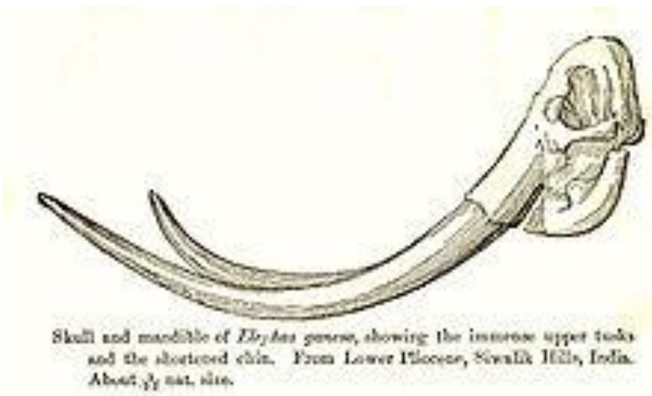

Figure 4.29: *Elephas ganesa* a fossil elephant from the Siwaliks.

Once connected to the Asian mainland, many species moved into India. The Himalayas were created in several upheavals. The Siwaliks were formed in the last and the largest number of fossils of the Tertiary period are found in these ranges.

The Siwalik fossils include Mastodons, hippopotamus, rhinoceros, Sivatherium, a large four-horned ruminant, giraffe, horses, camels, bison, deer, antelope, pigs, chimpanzees, orangutans, baboons, langurs, macaques, cheetahs, sabre-toothed cats, lions, tigers, sloth bear, Aurochs, leopards, wolves, dholes, porcupines, rabbits and a host of other mammals.

Many fossil tree species have been found in the intertrappean beds including *Grewioxylon* from the Eocene and *Heritieroxylon keralensis* from the middle Miocene in Kerala and *Heritieroxylon arunachalensis* from the Mio-Pliocene of Arunachal Pradesh and at many other places. The discovery of *Glossopteris* fern fossils from India and Antarctica led to the discovery of Gondwanaland and led to the greater understanding of continental drift. Fossil *Cycads* are known from India while seven *Cycad* species continue to survive in India.

Titanosaurus indicus was perhaps the first dinosaur discovered in India by Richard Lydekker in 1877 in the Narmada valley. This area has been one of the most important areas for paleontology in India. Another dinosaur known from India is *Rajasaurus narmadensis*, a heavy-bodied and stout carnivorous abelisaurid (theropod) dinosaur that inhabited the area near present-day Narmada river. It was 9 m in length and 3 m in height and somewhat horizontal in posture with a double-crested crown on the skull.Some scientists have suggested that the Deccan lava flows and the gases produced were responsible for the global extinction of dinosaurs however these have been disputed.

Himalayacetus subathuensis the oldest-known whale fossil of the family Protocetidae (Eocene), about 53.5 million years old was found in the Simla hills in the foothills of the Himalayas. This area was underwater (in the Tethys sea) during the Tertiary period (when India was an island off Asia). This whale may have been capable of living partly on land. Other fossil whales from India include *Remingtonocetus* approximately 43-46 million years old. Several small mammal fossils have been recorded in the intertrappean beds, however larger mammals are mostly unknown. The only major primate fossils have been from the nearby region of Myanmar.

Recent extinctions

Figure 4.30.

The exploitation of land and forest resources by humans along with hunting and trapping for food and sport has led to the extinction of many species in India in recent times. Probably the first species to vanish during the time of the Indus Vally civilisation was the species of wild cattle, *Bos primegenius nomadicus* or the wild zebu, which vanished from its range in the Indus valley and western India, possibly due to inter-breeding with domestic cattle and resultant fragmentation of wild populations due to loss of habitat.

Notable mammals which became or are presumed extinct within the country itself include the Indian / Asiatic Cheetah, Javan Rhinoceros and Sumatran Rhinoceros.[34] While some of these large mammal species are confirmed extinct, there have been many smaller animal and plant species whose status is harder to determine. Many species have not been seen since their description. *Hubbardia heptaneuron*, a species of grass that grew in the spray zone of the Jog Falls prior to the construction of the Linganamakki reservoir, was thought to be extinct but a few were rediscovered near Kolhapur.

Table 4.2: An estimate of the numbers of species by group in India is given below. This is based on Alfred, 1998

Taxonomic Group	World Species	Indian Species	% In India
Protista			
Protozoa	31250	2577	8.24
Total (Protista)	**31250**	**2577**	**8.24**
Animalia			
Mesozoa	71	10	14.08
Porifera	4562	486	10.65
Cnidaria	9916	842	8.49
Ctenophora	100	12	12
Platyhelminthes	17500	1622	9.27
Nemertinea	600		
Rotifera	2500	330	13.2
Gastrotricha	3000	100	3.33
Kinoryncha	100	10	10
Nematoda	30000	2850	9.5
Nematomorpha	250		
Acanthocephala	800	229	28.62
Sipuncula	145	35	24.14
Mollusca	66535	5070	7.62
Echiura	127	43	33.86
Annelida	12700	840	6.61
Onychophora	100	1	1
Arthropoda	**987949**	**68369**	**6.9**
Crustacea	35534	2934	8.26
Insecta			6.83
Arachnida	73440		7.9
Pycnogonida	600		2.67
Pauropoda	360		
Chilopoda	3000	100	3.33
Diplopoda	7500	162	2.16
Symphyla	120	4	3.33
Merostomata	4	2	50
Phorinida	11	3	27.27
Bryozoa (Ectoprocta)	4000	200	5
Endoprocta	60	10	16.66
Brachiopoda	300	3	1
Pogonophora	80		
Praipulida	8		
Pentastomida	70		
Chaetognatha	111	30	27.02
Tardigrada	514	30	5.83
Echinodermata	6223	765	12.29
Hemichordata	120	12	10
Chordata	48451	4952	10.22
Protochordata	2106	119	5.65
Pisces	21723	2546	11.72

Amphibia	5150	209	4.06
Reptilia	5817	456	7.84
Aves	9026	1232	13.66
Mammalia	4629	390	8.42
Toatal (Animalia)	**1196903**	**868741**	**7.25**
Grand Total (Protista + Animalia)	**1228153**	**871318**	**7.09**

Figure 4.31: A praying montis.

Figure 4.32: *Harpegnathos saltator*.

Fig 4.33: An Idiopid spider endemic to India

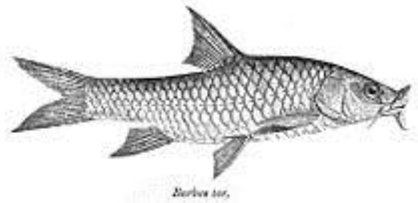

Fig 4.34: Deccan Mahseer *Tor khudree*.

Some species of birds have gone extinct in recent times, including the Pink-Headed Duck (*Rhodonessa caryophyllacea*) and the Himalayan Quail (*Ophrysia superciliosa*). A species of warbler, *Acrocephalus orinus*, known earlier from a single specimen collected by Allan Octavian Hume from near Rampur in Himachal Pradesh was rediscovered after 139 years in Thailand. Similarly, the Jerdon's Courser (*Rhinoptilus bitorquatus*), named after the zoologist Thomas C. Jerdon who discovered it in 1848, was rediscovered in 1986 by Bharat Bhushan, an ornithologist at the Bombay Natural History Society after being thought to be extinct.

Animals

Invertebrates

- Molluscs
  - List of non-marine molluscs of India
- Arachnids
  - Spiders of India
- Insects
  - Coccinellidae
    - Ladybird beetles of India
  - Odonata
    - Dragonflies and damselflies of India
  - Lepidoptera
    - Butterflies of India
    - Papilionid butterflies of India
    - Pierid butterflies of India
    - Nymphalid butterflies of India
    - Lycaenid butterflies of India
    - Hesperid butterflies of India
    - Riodinid butterflies of India
    - Moths of India
  - Hymenoptera
    - Ants of India

Vertebrates

- Fishes of India
- Amphibians of India
- Reptiles of India
  - Snakes of India
- Birds of South Asia
- Mammals of India

Threatened species

Many plants and animals are threatened or endangered due largely to habitat loss and population pressure apart from hunting and extraction. India stands out as one of the few countries with high human populations as well as a high number of threatened species.

Table 4.3: Threatened plant species.

Threat Category (IUCN)	**Number of Species**
Extinct	19
Extinct/Endangered	43
Endangered	149
Endangered/Vulnerable	2
Vulnerable	108
Rare	256
Indeterminate	719
Insufficiently Known	9
No information	1441
Total	**3120**

Threatened Animal species

Biodiversity is not distributed uniformly over the earth. Some areas, particularly along the tropics, are rich in species. Many species in these areas are threatened with extinction. However, the fund for conservation is rather limited and hence it is important to fix priority areas of conservation. In 1988 British ecologist, *Norman Myres* forwarded a concept called hotspots to identify the most major criteria for designating an area as hotspot are : (i) richness in endemic species, and (ii) impact by human activities. Endemic species are those restricted to certain localized areas of the earth. Evolutionary history has endowed species with ecological characteristics that respond to the environment they inhabit. However, most species are rare and restricted, because their ecological requirements are only met over by a small area and because they are not capable of dispersing great distances to other suitable habitats.

Plant diversity is the biological basis for hotspot designation. To qualify as a hotspot, a region must support 1,500 endemic plant species, 0.5 percent of the global total. Existing primary vegetation is the basis for assessing human impact in a region; to qualify as a hotspot, a region must have lost more than 70 percent of its original habitat. Identification of hotspot would help pin pointing priority areas for conservation. According to the classification of Norman Myres' there are 25 hotspots scattered in different parts of the world. Even though the 25 biodiversity hotspots together represent 1.4 percent of the earth's land area, they contain 44 percent of all plant species and 35 percent of all terrestrial vertebrate species in the world. Each of these hotspots is under severe pressure due to anthropogenic interventions and has already lost at least 70 percent of its original natural vegetation India is part of two hotspots- *Indo-Burma* (earlier Eastern Himalayas) and *Western Ghats and Sri Lanka.* Of late, conservationists named nine new 'Biodiversity Hotspots', making the total to 34, which also include the *Himalaya**s.***

Hotspot conservation initiatives

Only a small percentage of the total land area within biodiversity hotspots is now protected. Several international organizations are working in many ways to conserve biodiversity hotspots**.**

- Critical Ecosystem Partnership Fund (CEPF) is a global program that provides funding and technical assistance to nongovernmental organizations and other private sector partners to protect biodiversity hotspots. CEPF has provided support to more than 1,000 civil society groups working locally to conserve hotspots in Africa, Asia, and Latin America. CEPF is a joint initiative of The Global Environment Facility, The John D. and Catherine T. MacArthur Foundation, L'Agence Française de Développement, The Ministry of Finance of the Government of Japan, Conservation International and The World Bank.
- Conservation International applies innovations in science, economics, policy and community participation to protect the Earth's richest regions of plant and animal diversity including: biodiversity hotspots, high-biodiversity wilderness areas and important marine regions. CI works in more than 40 countries on four continents, with headquarters near Washington, D.C.
- The World Wildlife Fund has derived a system called the "Global 200 Ecoregions", the aim of which is to select priority Ecoregions for conservation within each of 14 terrestrial, 3 freshwater, and 4 marine habitat types. They are chosen for their species richness, endemism, taxonomic uniqueness, unusual ecological or evolutionary phenomena, and global rarity. All biodiversity hotspots contain at least one Global 200 Ecoregion.
- Birdlife International has identified 218 "Endemic Bird Areas" (EBAs) each of which hold two or more bird species found nowhere else. Birdlife International

has identified more than 11,000 Important Bird Areas all over the world.Plantlife International coordinates several projects around the world aiming to identify Important Plant Areas.

- Alliance for Zero Extinction is an initiative of a large number of scientific organizations and conservation groups who co-operate to focus on the most threatened endemic species of the world. They have identified 595 sites, including a large number of Birdlife's Important Bird Areas.
- The National Geographic Society has prepared A World map of the hotspots and ArcView shapefile and metadata for the Biodiversity Hotspots including details of the individual endangered fauna in each hotspot, which is available from Conservation International.

These initiatives are all based on scientific criteria and quantitative thresholds.

CHAPTER- VI

PHYTOGEOGRAPHY OF INDIA: AN OUT LINE

Due to temperature extremes and marked seasonal fluctuations throughout the year, climatic conditions of India become of much ecological interest. Moreover, soils in different parts of the country also differ chiefly from each other. These all make the vegetation of the country worthy of ecological investigations. We would study in detail all such aspects here.

Soils of India

On the basis of their nature and composition, soils of India have been classified into six major types, which are shown in Figure 1.

1. Alluvial soils

These occur chiefly in the Indo Gangetic plain covering the states of Punjab and Haryana in the northwest, U.P. and Bihar in the north, and Bengal and parts of Meghalaya and Orissa in the north-east. Besides plains, this soil also occurs in the east coast deltas arid terrace, deltaic and lagoon alluvium of Peninsular India, The soil is rich in loams and clay components in Punjab and western Ganga plains, the loam component increasing and sand decreasing in the central Ganga plains, where the much calcareous kankar is common. The soil is generally alkaline or neutral in reaction. In Ganga-Brahmputra plains soil contains very fine particles varying from loams to very fine silt clay.

2. Black soils

This type of soil is common in the Deccan traps including Maharashtra, Mysore and M.P., though also present in the Krishna-Tungabhadra basin of Tamilnadu. In western Deccan, these are indeed black-cotton soils — regur, whereas in the eastern part these are medium light black type. Soils of Vindhya and adjacent hills are also called 'brown soils'. Black soils are predominantly clay, with patches of clay loams, loams and sand loams.

3. Red soils

They cover large are as in south, and in the north-east of the Peninsula. Such soils occur in Andhra Pradesh, Tamilnadu, and parts of Bihar, Orissa, U.P and West

Bengal. Their red colour is due to high proportion of iron components. These are mainly sandy to loam in texture, with gravels on upper slopes, then sandy soils, deeper loamy soils on lower, slopes, and loams or rather clay in the valley bottoms. In addition, clay of true as well as low laterites also occurs in this zone in Western Ghats and Kerala respectively. Moreover, there are also a number of red, yellowish and whitish clays in some parts of South-west inda.

4. Skeletal (mountain) soils

They occur in north-western hills or the Aravallis, where they are stony sandy hillfoot fans and slope colluvium, and in the humid south and east of the Himalayas and in Meghalaya where these are more clayey in texture.

5. Desert soils

These cover large parts of Rajasthan and the semi-desert areas of the Rann of Kutch.

6. Laterite soils (Latosols)

These are present in the Western Ghats, the northern half of the Eastern Ghats, eastern margins of Chota Nagpur plateau, Meghalaya, few patches around Kathiawar, and in two areas in the centre of the peninsula north of Bangalore and west of Hyderabad. These soils have porous clay rich in hydroxides bf iron and aluminium. At low elevations, such soils are suitable for paddy cultivation, whereas those at higher elevations, these favour the growth of coffee, rubber, tea and *Cinchona*.

Climate of India

Indian subcontinent lies entirely to the north of the equator between latitudes 8° and 36°N. India is supposed to be a tropical country although, the northern part — the Gangetic Plain belongs geographically to the north temperate zone of the world. The climate of the country is chiefly influenced by the physiography of several hills and ranges, as Himalayan range, mountain ranges of Meghalaya and Arunachal, and the Western Ghats together with the Nilgiris and other hills in south. The climate of India is of monsoon type. According to Meteorological Department, Government of India, there are following four seasons in the country.

1. The seasons of the north-east monsoon

a. The 'cool season', from mid-December to February,

b. The 'hot dry season', from March to mid-June.

2. The seasons of the south east monsoon.
c. The ‘wet season', from mid-June to mid-September,
d. The 'season of retreating monsoon', from mid-September to mid-December.

Climatic regions of India

India, as result of a number of climatic factors operating in various kinds of physiographic situations present a number of geographical climate types. As India is a tropical country, rainfall and not temperature, has been taken as the chief criterion for climate types. On the basis of annual precipitation, the country has been divided into the following four climatic regions.

1. Wet zone

Rainfall is very heavy, more than 200 cm. This zone includes the western slopes of the Western Ghats and hills of Meghalaya and Bengal, and the tarai regions of Bihar and U.P. The northern half of the western slopes has long, and the southern half short dry seasons. The vegetation is chiefly of evergreen forests type, and paddy is the main crop.

2. **Intermediate zone**

Rainfall is heavy, between 100 and 200 cm. This zone includes part of West Bengal, Bihar, Orissa, eastern M.P., foot-hills of Himalayas, northern U.P., H.P., Jammu, north-east Andhra Pradesh, eastern slopes of Western Ghats and east Tamilnadu. The chief vegetation are deciduous forests where most of the trees shed their leaves during hot weather.

3. Dry zone

Rainfall is moderate, between 50 and 100 cm. This zone includes Punjab, U.P., Delhi, western M.P., Gujarat, Maharashtra, Karnataka, southern Andhra Pradesh and Tamilnadu, thus comprising Carnatic, north-west Deccan, and upper Ganges plain and upper Punjab plain. The chief vegetation is of dry, deciduous and thorn scrub type. In some localities, there are present dry deciduous forests of the type found in intermediate zone. Wheat and millets are the chief agricultural crops.

4. **Arid zone**

Annual rainfall is very low, less than 50 cm. This zone includes the north-west lowland and north-west plateau, thus covering whole of the western part of the country i.e. south western part of Punjab, Rajasthan, and north-west Gujarat. The natural vegetation is thorn forest with large areas of desert and semi-desert conditions.

Floristic (Botanical) Regions of India

As Indian sub-continent is characterised with a variety of climate types, flora of the country is also correspondingly of different types in different parts. For the study of flora, the country has been divided into following nine floristic regions (Fig. 2). (i) Western Himalayas, (ii) Eastern Himalayas, (iii) West Indian Deserts, (iv) Gangetic plain, (v) Assam, (vi) Central India, (vii) Malabar, (viii) The Deccan, and (ix) Andamans.

I. Western Himalayas

It extends from central region of Kumaon to North West region of Kashmir. Altitudinally there are three zones of vegetation corresponding to three climatic belts.

1. Submontane or lower region (tropical and subtropical)

From about 1,000 to 5,000 ft, above sea level in regions of Siwaliks and adjacent areas. The forest is dominated by timber trees of *Shorea robusta.* In riverain regions trees of *Dalbergiasissoo* aredominant, while in more moist soils, dominants are *Cedrela toona*, *Ficus glomerata* and *Eugenia jambolana.* In isolated patches of grasses, there are present trees of *Acacia catechu* and *Butea monosperma.* In dry belts towards west, *Shonea robusta* is replaced by such xerophy tes as *Zizyphus*, *Carissa*, *Acacia*, etc. with.thorny succulent euphorbias on slopes. *Pinus roxburghti begins* to appear at 3,000 to 5,000 ft. Ground vegetation is poor.

2. Temperate or montane zone

From 5,000 to 11,675 ft. above sea level. At about 5,500 ft. *Pmus.longifolia* is generally replaced by *P. excelsa. From* 5,500 ft. to 6,000 ft. *Cedrus deodara* is quite abundant forming pure forest stands. At these altitudes *Quercus incana* also grows as separate patches. In the inner Himalayas in Kashmir, *Betula* (birch), *Salix* (cane) and *Populus* (poplar) are abundant on certain soil types. At higher altitudes, *Aescultis indica* (horse chestnut), *Quercus semecarpifoiia*, *Q. dilatata* alongwith me conifers such as *Abies pindrow Picea morinda, Cupressustorulosa, Tuxus baccata* etc. are most common components of vegetation. *Rhododendron companulatum* grows at higher altitudes. *In* inner valleys on dry mountains, *Pinus gerardiana* is also found. In dry areas of Punjab, wheat and barley are cultivated, while in wet valley of Kashmir, rice is the common crop. Other common plants grown in Kashmir are, saffron *(Croccus sativus),* apples, peaches, walnuts, almonds etc.

3. Alpine zone

It is the limit of tree growth at about 12,000 ft. known as timber or tree line, where the plants' height is considerably reduced. Plants are mostly dwarfed and cushion shaped shrubs and grasses. At about 15,000 ft. and above-snow line, plant growth is almost nil. On lower levels of this zone, some rhododendrons *Betula utilis* and small junipers are present. Above this zone there are present many types of herbs, with short period of vegetative growth and flowering. These include *Primula, Potentilla, Polygonum, Geranium, Saxifraga, Aster* etc.

II. Eastern Himalayas

It consists of regions of Sikkim and extends in the east up to NEFA. In its vegetational zones, it is similar to the western Himalayas. On the whole, the eastern Himalayas have more tropical elements, greater variety of oaks and rhododendrons and less of conifers than the western Himalayas. The chief differences are the higher rainfall and warmer conditions in this part of Himalayas. The tree and snow lines are higher by about 1,000 ft. than the corresponding lines on western Himalayas. Species diversity and vegetation density are higher in the east. This region is also divided into three zones.

1. Submontane zone

Due to warm and humid weather, it is typically tropical with dense forests *of Shored rubusta.* It extends from the plain foot of the hill up to 6,000 ft. altitude. In riverain area there are forests of *Dalbergia sissoo* and *Acacia catechu.* Mixed forests of deciduous trees like *Sterospermum, Cedrela toona, Bauhinia, Anthocephalus cadambd, Lagerstroemia pavriflora* are predominant. Tall trees like *Albizzia procera, Salmalia, Artocarpus chaplasha,* bamboo *(Dendrocalamus)* are important.

2. Temperate zone

It ranges between 6,000 to 12,000.ft. altitude above sea level. The lower region has several species of oaks, such as *Quercus lemellosa* and *Q. lineata, Michelia, Cedrela* and *Eugenia.* The upper region which is cooler has such conifers as *Juniperus, Cryptomeria, Picea, Abies* and *Tsuga.* One bamboo, *Arundinaria* sp. is also common. Some rhododendrons are also common at higher elevations.

3. Alpine zone

It is above 12,000 ft. where vegetation is devoid of trees. Shrubby growth of *Juniperus* and *Rhododendron* is found in grassy areas.

III. West Indian deserts (Indus plain)

This region consists of parts of Rajasthan, Kutch, Delhi and part of Gujarat. The climate is characterised by very hot and dry summer, and cold winter. Rainfall is less than 70 cm. The plants are mostly xerophytic, such as *Acacia nelotica*, *Prosopis spicifera, P. juliflora, Salvador a_pleoides, S: persica, Tecomella, Capparis aphylla, Tamarixdioica,* and *Zizyphus nummularia.* The ground vege-"tation is mostlyrepresented by small *Calotropissp.,Panicum antidotale*, *Eleusine* sp., *Tribulus terrestris* etc. Some common species used in plantations are *Saccharum munja, Panicum antidotale, Cenchrus ciliafis, Capparis aphylla, Tamarix articulata, Prosopis spicifera, P. juliflora, Acacia leucophloea and A. Senegal.*

IV. Gangetic plain

This region comprising Uttar Pradesh, Bihar and Bengal is most fertile region. The chief climatic factors, the temperature and rainfall together are responsible for distinct type of vegetation. Rainfall is less than 70 cm in west U.P., being more than 150 cm in Bengal. Vegetation is chiefly of tropical moist and dry deciduous forest type. In north-western U.P., near foothills of the Himalayas, *Dalbergia sissoo* and *Acaciamelotica* are most common. In south-west U.P., there are desert areas, where characteristic species are *Capparis aphylla, Saccharum munja, Acacia nelotica* etc. In eastern U.P., *Butea monosperma* (dhak), *hiadhuca indica (mahaa),Terminalia arjuna (ai)un),,BuchgnQnia lanzan* (chiraunji), *Dio-spyros melanoxylon* (tendu), *Gordia tnyxa* (lisora), *Sterculia ureris, Bosweflia serrata* (salai), *Acacia catechu (Khair), Azadirachia indica* (neem), *Mangifera indica* (mango), *Ficus bengdlensis* (bargad),F. *religiosa* (pipal) are most dominant trees. Besides them, some weeds and grasses like

Xdnthium strumarium, Cassia tor a, Argemone mexicana, Amaranthus sp., *Pertstrophe bicalyculata, Dichanthium annulatum, Bothriochloa pertusa* etc. are also present. In Gangetic delta region extreme swampy and halophytic vegetation is common, where dominant species are *Rhizophora mucronata, R. conjugata, Acanthus ilicifolius, Kandelia rheedii, Bruguiera gymnorhiza, Ceriops roxburghiana etc.*

V. Assam

This region receives the heaviest rainfall, with Cherrapunji as much as more than 1000 cm. The temperature and wetness are very high which are responsible for dense tropical evergreen forests. Some of the important trees are *Dipterocarpus macrocarpus, Mesuaferrea, Michelia champaca, Shorea robusta, Artocarpus chaplasha, Alstonia scholaris, Sterculia alata, Lagerstroemia flos-regina, Ficus elastica etc.* Some bamboos, as *Bambusa pallida, Dendrocalamus hamiltonii. Calamus* sp. grasses as *Imperata cylindrica, Saccharum arundinaceum, Themeda sp., Phragmites* sp., and insectivorous plants like *Nepenthes* sp. are also present. In northern cooler regions, *Alnus nepalensis, Rhododendron arboreum, Betula* sp. are also found. In hilly tracts, some conifers like *Pinuskhasiya* and P. *insularis* are also present.

VI. Central India

It comprises Madhya Pradesh, parts of Orissa, and Gujarat Depending upon the amount of rainfall, forests have developed into thorny, mixed deciduous and sal types. The forest vegetation is chiefly constituted by *Tectorta grandis, Diospyros melanoxylon, Butea monosperma, Terminaliatomentosa and Dalbergia latifolia.* The thorny vegetation consists of *Cdrissai spinarum, Tizyphus rotundifolia, Acacia leucophloea, A. catechu, Butea frondosa* etc.

VII. Malabar

This region comprises the western coast of India extending from Gujarat in the north to the Cape Camorin in the south. Rainfall is heavy. The vegetation is of four types-tropical moist evergreen forests, mixed deciduous forests, subtropical or temperate evergreen forests and the mangrove forests. The tropical wet evergreen forests are very luxuriant and multistoried, with such tall trees as *Dipterocarpus indicus, Sterculia alata, Cedrela toona, Tectona grandis* and *Dalbergia latifolia, Bamboos, like Dendrocalamus strictus and Bambusaarundinacea* are also present: In the Nilgiri hills, there are temperate evergreen forests of such trees as *Euryajaponica*, *Michelia nilagirica* and *Gordonia obtusa* known as the sholas.

VIII. The Deccan

This region is drier with rainfall of about 10 cm. It includes Andhra Pradesh, Tamilnadu and Karnataka. It has a central hilly plateau with forests of *Boswellia serrata*, *Tectona grandis* and *Hardwickia pinnata*, and the low eastern dry Gororriandal coast, with tropical dry evergreen forests of *Santalum album* (chandan), *Cedrelai toona* and plants like *Capparis, Phyllanthus, Euphorbia sp.*

IX. Andamans

It lias a wide range of spreading coastal vegetation like mangroves, beech forests and in the interior evergreen forests of tall trees. There are some pockets of dry areas also. Important species of the island are *Rhizophora*, *Mimusops*, *Calophyllum*, *Dipterocarpus*, *Lagerstroemia* and *Terminalia*. Most of the area is now cleared for paddy and sugarcane cultivations.

Vegetation of India

This subcontinent has been affected worst by human influences since long time. Due to this, climax formations are very much altered and/of destroyed for agriculture and other similar purposes. The present vegetation has suffered indeed from effects of plants, animals, soil, climate and man. Therefore, the vegetation of the country that we see around us is much interfered. The most important factors used in the classification of vegetation are rainfall, temperature, biotic influences, and life forms. In India, there are two most common types of plant formations, (i) forest and (ii) grassland.

I. Forest vegetation

Indian forests have generally been classified on the basis of temperature into four major types— (i) tropical, (ii) montane subtropical, (iii) temperate, and (iv) alpine.

1. Tropical forests

Common in the warmer plains, ranging from very dense, multistoreyed of diverse trees, shrubs and lianas in areas of high rainfall to dry, scrub jungles of thorny bushes in isolated patchesin dry areas. Thus, they are of two types moist tropical and dry tropical forests.

A. Moist tropical forests

On the basis of degree of wetness these are of the following three principal types.

i. *Tropical wet evergreen forests:*

Where annual rainfall is over 250 cm as in West Coast, Assam, Bengal and Andaman islands. They are multistoreyed, made up of small trees, shrubs, epiphytes, lianas and dense ground vegetation. The dominant members are such trees as *Dipterpcarpus, Hopea, Artocarpus, Mangifera, Emblica, Michelia, Eryatamia, Lagerstroemia, Ixora* and some climbers.

ii. Tropical moist semi-evergreen forests

Better developed in northern than the southern region of country. Trees shed their leaves for brief period. In north, they develop in north Assam and Bengal and parts of Orissa receiving heavy rainfall. There are some; evergreen plants also as *Artocarpus, Michelia, land, Eugenia.* The deciduous trees are *Terminalia*, *Teranieles* and *Shorea.*

iii. Tropical moist deciduous forests

*S*ome trees shed leaves for brief period, some are evergreen and semi-evergreen. They are common in moist areas of Kerala, Karnataka and south M.P. in south and parts of north U.P, M.P, Bihar, Bengal and Orissa in north. The well known teak and sal forests belong to this category. In south India, moist deciduous forests are dominated by species of *Terminalia, Grewia, Gariya, Salmala, Tectona grandis, Adina cordifalia, Melia, Albizzia, and Dalbergia* etc. In the northern half, *Shorea robusta* is dominant in Gorakhpur and Tarai regions of U.P., Assam and north Bengal. Other associates of sal are *Terminalia tomentosa*, *Dillenia* sp., *Eugenia* sp. etc.

B. Dry tropical deciduous forests

Most of their trees remain leafless for several weeks in dry season. In north such forests are found in the Punjab, UP, Bihar and Orissa in regions which are neither wet nor too dry. Trees are of moderate size (2.5 meters tall), with sparse canopy. Thorny scrubs, grasses and some bamboos are also present in some regions. In Punjab and west U.P. forests, *Anogeissus latifolia, Acacia catechu, Terminalia tomentosa,* *Boswellia serrata* are dominants with subdominance of *Dendrocalamus strictus, Emblica officinalis, Wdodfordia floribunda etc.* Forests of *Shorea robusta* are also found as scattered in wet areas. In soudi, such forests are present in dry areas of Maharashtra, Tamilnadu, M.P. and Karnataka. These are mixed forests of deciduous treec with .scattered patches of densely growing grasses intermixed with shrubs. *Terminalia, Anogeissus latifolia, Tectona grandis, Diospyros melanoxylon, Boswellia* sp. forms the top layer, followed by smaller plants like *Dendrocaldmus, Bambusa, Lantana*, *Helicteris* etc. Common grasses are *Panicum*, *Andropogon* and *Hetero-pogon.*

2. Montane subtropical forests

These are found on hills of south India, as Nilgiri, Mahabaleshwar and Pachmarhi, between altitudes of 3,000 to 5,600 ft. These are cooler than the tropical and warmer than the temperate forests. In southern parts the common trees are *Eugenia, Actinodaphne*, *Canthium*, *Mangifera* and *Ficus*, and climbers are *Piper trichostachyon, Gnetum scandens, Snilax macrophylla* etc. The northern areas have rather tall trees. In eastern Himalayas due to higher humidities, bamboos, many epiphytes including orchids and ferns become abundant. Most of-the trees are evergreen. The floristic description of eastern and western Himalayas has already been given.

3. Temperate forests

They occur above 5,300 ft altitude, chiefly on mountains of Himalayas and Nilgiri. In Himalayas, oaks and conifers are abundant their distribution has already been described. Oaks form relatively stable evergreen pure stands. The southern temperate vegetation is chiefly represented by the sholas near Ootacamund, Nilgiri hills and Tamilnadu. The forests are very dense with extensive growth of grasses and evergreen tall trees, *like Balanocarpus utilis*, *Hopeaparviflora*, *Artocarpus hirsuta*, *Salmalia malbaricum* etc. Their branches are clothed with mosses, many woody climbers, ferns and other epiphytes.

4. Alpine vegetation

Sometimes they are subdivided as sub-alpine forests, alpine scrubs, moist alpine scrubs and dry alpine scrubs. They are extensive throughout the Himalayas above 11,000 ft. The tree height becomes lesser with increasing altitude, being replaced finally by sparse growth of small plants like *Sedum*, *Primula*, *Saxifraga* and lichens etc. The details of their flora are already given in description of the Himalayas.

II. Grassland vegetation

In India, natural grasslands are hardly present, and most of them arc maintained in their present serai stages due to biotic influences. Thus, grasslands are not climax formations but have developed secondarily by the forests' destruction. The two major factors that resulted into their secondarily development are edaphic and biotic. The grasslands of India are of three major types.

Table 4.1: Different eight types of grasslands of India.

Grassland type	Dominant species	Other common species	Environmental conditions	Chief regions of distribution
1. Sehima Dicnanthium	*Sehima sulcatum* *S. nervosum* *Dichanlhium aunulatum* *Chrysopogon montanus,* *Tkemeda quadrivahis*	*Ischaemum rogosum* *Iseilema iaxum* *Heteropogon contortus*	Black soil	Maharashtra, M.P, south-west U.P. and parts of Tamilnadu and Karnataka
2. Dichanthium Cenchrus	*Dichanthium annulatum,* *Cenchrus ciliaris* In some grazed areas replaced by sparse annuals	*Bothriochloa pertusa* *Heteropogon contortus,* *Cynoavn dactylon,* *Eragrostis* spp, *Dactylocteniu aegypticum*	Sandy loam soils	Plains of Panjab.Haryana, Delhi, Rajasthan, saurashtra, east M.P. coastal Maharashtra and Tamilnadu
3. Phragmites saccharum	*Pharagmites karka* *Saccharum spontaneum,* *Imperata cylmdrica.* *Bothriochloa pertusa*		Marshy areas	Tarai areas of north U.P; Bihar, Bengal, Assam, and Tamilnadu (Sundarbans and kaveri delta)
4. Bothriochloa	*Bothriochloa odorata*		Paddy tracts with heavy rainfall	Lonavala tract of Maharashtra
5.Cymbopogon	*Cymbopogon*	*Themeda, Heteropogon, Aristida*	Low hills	Western Ghats, Vindyas, Satpura, Aravali, Chota Nagpur
6. Arundinella	*Arundinella nepalensis, A. setosa, Themeda anathera*	*Chrysopogon*	High hills	Western Ghats, Nilgiris, lower Himalayas (Assam to Kashmir)

7. Deyeuxia Arundinella	*Deyeuxia, Arundinella, brachypodium, Bromus, Festuca*		Temperate climate	Upper Himalayas between 6,200 to 10,000 from Assam, Bengal through U.P to Punjab and H.P.
8. Deschampsia Deyeuxia	*Deyeuxia, Deschampsia, Poa, Stipa. Glyceria, Festucd*	*caespitosa, Trisetum spicatum* (beyond 16, 000)		Himalayas (above 8,300) Kashmir

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