Biogeography

BIOGEOGRAPHY

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Preface

This branch of geography is concerned with the multitudinous forms of plant and animal life which inhabit the densely populated zone over the earth's surface, as well as the complex biological activities which are controlled by natural environment.

Biogeography deals with the geography, ecology, and history of life where it lives, how it lives there, and how it came to live there. It has three main branches analytical biogeography, ecological biogeography, and historical biogeography. Historical biogeography considers the influence of continental drift, global climatic change, and other large-scale environmental factors on the long-term evolution of life. Ecological biogeography looks at the relations between life and the environmental complex. Analytical biogeography examines where organisms live today and how they spread. It may be considered as a division of ecological biogeography.

Ecological explanations for the distribution of organisms involve several interrelated ideas. First is the idea of populations, which is the subject of analytical biogeography. Each species has a characteristic life history, reproduction rate, behaviour, means of dispersion, and so on. These traits affect a population's response to the environment in which it lives. The second idea concerns this biological response to the environment and is the subject of ecological biogeography. A population responds to its physical surroundings (abiotic environment) and its living surroundings (biotic environment). Factors in the abiotic environment include such physical factors as temperature, light, soil, geology, topography, fire, water, water and air currents; and such chemical factors as oxygen levels, salt concentrations, the presence of toxins, and acidity. Factors in the biotic environment include competing species, parasites, diseases, predators, and humans. In short, each species can tolerate a range of environmental factors. It can only live where these factors lie within its tolerance limits.

Biogeography, study of the geographic distribution of plants and animals. It is concerned not only with habitation patterns but also with the factors responsible for variations in distribution. Biogeography is concerned with the phenomena of the biosphere. More specifically and traditionally, biogeography has concerned itself with the study of the geographical aspects of plant and animal life, especially in terms of their distributions.

This book, written as an introductory manual on biography caters perfectly to needs of students of geography or the biological sciences. Serving as an essential key for understanding biodiversity, biogeography is one the most relevant, as well as increasingly studied scientific disciplines today.

—*Dr. Udhav Eknath Chavan*

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Introduction to Biogeography

INTRODUCTION

Biogeography deals with the geography, ecology, and history of life where it lives, how it lives there, and how it came to live there. It has three main branches analytical biogeography, ecological biogeography, and historical biogeography. Historical biogeography considers the influence of continental drift, global climatic change, and other large-scale environmental factors on the long-term evolution of life. Ecological biogeography looks at the relations between life and the environmental complex. Analytical biogeography examines where organisms live today and how they spread. It may be considered as a division of ecological biogeography.

The ecological and historical biogeography of animals and plants, and, in doing so, it considers human involvement in the living world. It is designed to lead students through the main areas of modern biogeographical investigation. Basic ideas are carefully explained using numerous examples from around the world.

What Is Biogeography?

Biogeographers study the geography, ecology, and evolution of living things.

- Ecology—environmental constraints on living
- History and geography—time and space constraints on living

Biogeographers address a misleadingly simple question: why do organisms live where they do? Why is the speckled rangeland grasshopper confined to short-grass prairie and forest or brushland clearings containing small patches of bare ground? Why does the ring ouzel live in Norway, Sweden, the British Isles, and mountainous parts of central Europe, Turkey, and south-west Asia, but not in the intervening regions? Why do tapirs live only in South America and South-east Asia? Why do the nestor parrots—the kea and the kaka—live only in New Zealand? Why do pouched mammals (marsupials) live in Australia and the Americas, but not in Europe, Asia, Africa, or Antarctica? Why do different regions carry distinct assemblages of animals and plants? Two groups of reasons are given in answer to such questions as these—ecological reasons and historical-cum-geographical reasons.

Ecology

Ecological explanations for the distribution of organisms involve several interrelated ideas. First is the idea of populations, which is the subject of analytical biogeography. Each species has a characteristic life history, reproduction rate, behaviour, means of dispersion, and so on. These traits affect a population's response to the environment in which it lives. The second idea concerns this biological response to the environment and is the subject of ecological biogeography. A population responds to its physical surroundings (abiotic environment) and its living surroundings (biotic environment). Factors in the abiotic environment include such physical factors as temperature, light, soil, geology, topography, fire, water, water and air currents; and such chemical factors as oxygen levels, salt concentrations, the presence of toxins, and acidity. Factors in the biotic environment include competing species, parasites, diseases, predators, and humans. In short, each species can tolerate a range of environmental factors. It can only live where these factors lie within its tolerance limits.

Speckled Rangeland Grasshopper

This insect *(Arphia conspersa)* ranges from Alaska and northern Canada to northern Mexico, and from California to the Great Plains. It is found at less than 1,000 m elevation in the northern part of its range and up to 4,000 m in the southern part. Within this extensive latitudinal and altitudinal range, its istribution pattern is very patchy, owing to its decided preference for very specific habitats. It requires short-grass prairie, or forest and brushland openings, peppered with small pockets of bare ground. Narrow-leaved grasses provide the grasshopper's food source. The bare patches are needed for it to perform courtship rituals. These ecological and behavioural needs are not met by dense forest, tall grass meadows, or dry scrubland. Roadside meadows and old logged areas are suitable and are slowly being colonized. Moderately grazed pastures are also suitable and support large populations.

Even within suitable habitat, the grasshopper's distribution is limited by its low vagility. This is the result of complex social behaviour, rather than an inability to fly well. Females are fairly sedentary, at least in mountain areas, while males make mainly short, spontaneous flights within a limited area. The two sexes together form tightly knit population clusters within areas of suitable habitat. The clusters are held together by visual and acoustic communication displays.

Ring Ouzel

The biogeography of most species may be explained by a mix of ecology and history. The ring ouzel or 'mountain blackbird', which goes by the undignified scientific name of *Turdus torquatus*, lives in the cool temperate climatic zone, and in the alpine equivalent to the cool temperate zone on mountains. It likes cold climates. During the last ice age, the heart of its range was probably the Alps and Balkans. From here, it spread outwards into much of Europe, which was then colder than now. With climatic warming during the last 10,000 years, the ring ouzel has left much of its former range and survives only in places that are still relatively cold because of their high latitude or altitude. Even though it likes cold conditions, most ring ouzels migrate to less severe climates during winter. The north European populations move to the Mediterranean while the alpine populations move to lower altitudes.

BIOGEOGRAPHY DEFINITION

Biogeography refers to the distribution of various species and ecosystems geographically and throughout geological time and space. Biogeography is often studied in the context of ecological and historical factors which have shaped the geographical distribution of organisms over time. Specifically, species vary geographically based on latitude, habitat, segregation (e.g., islands), and elevation. The subdisciplines of biogeography include zoogeography and phytogeography, which involve the distribution of animals and plants, respectively.

TYPES OF BIOGEOGRAPHY

There are three main fields of biogeography: 1) historical, 2) ecological, and 3) conservation biogeography. Each addresses the distribution of species from a different perspective. Historical biogeography primarily involves animal distributions from an evolutionary perspective. Studies of historical biogeography involve the investigation of phylogenic distributions over time. Ecological biogeography refers to the study of the contributing factors for the global distribution of plant and animal species. Some examples of ecological factors that are commonly studied include climate, habitat, and primary productivity (the rate at which the plants in a particular ecosystem produce the net chemical energy). Moreover, ecological biogeography differs from historical biogeography in that it involves the short-term distribution of various organisms, rather than the long-term changes over evolutionary periods. Conservation biogeography seeks to effectively manage the current level of biodiversity throughout the world by providing policymakers with data and potential concerns regarding conservation biology.

Biogeography Support Evolution

Biogeography provides evidence of evolution through the comparison of similar species with minor differences that originated due to adaptations to their respective environments. Over time, the Earth's continents have separated, drifted apart, and collided, resulting in the creation of novel climates and habitats. As species adapted to these conditions, members of the same species that had been separated geographically diverge, resulting in the eventual formation of distinct species. This knowledge is important, as by understanding how adaptations occurred in response to changing environments in the past, we can apply this knowledge to the future.

Example: The Galapagos Islands

One of the most famous examples of biodiversity in support of evolution is Charles Darwin's study of finches on the Galapagos Islands, which resulted in his book *On the Origin of Species*. Darwin noted that the finches on the mainland of South America were similar to those located on the Galapagos Islands; however, the shape of the bills differed depending on the type of food available on each island.

The islands had once been a part of the South American mainland, but the two land masses were subsequently separated and drifted apart. The result was the creation of novel habitats and food sources available for the species residing in each of these regions.

Therefore, each finch species had adapted to the local environment through the selection of alleles which promoted survival, eventually resulting in speciation. Islands are excellent for the study of biogeography because they consist of small ecosystems that can easily be compared to those of the mainland and other nearby regions. Moreover, since they are an isolated region, invasive species and the associated consequences for other organisms within the ecosystem can be readily studied. By studying such changes over time, the evolution of distinct species and ecosystems becomes apparent.

INTRODUCTION TO BIOGEOGRAPHY AND CONSERVATION BIOLOGY

The first requirement in any subject is to define the limits and the connections in it. The textbook standard definition of biogeography is that it is the study of the distributions of species over space and time and the causes of those distributions. It has two basic components: descriptive biogeography and ecological biogeography.

The first part studies the geography of species and the second part deals in the causes of those distributions. Clearly the first part is a necessary component, but it is the second part that is more exciting. The subject as a whole is dynamic because its subjects - biological populations and species- respond dynamically to causative factors over time and space, and because it is a relatively young science.

The time scales which you will see are important in biogeography range from days, weeks, or a few months, i.e. periods we can describe as ecological time, to millions of years, which constitute evolutionary or geological time scales. Physical events or changes driving these dynamics range from rapid effects of nonindigenous species (also called alien species) introductions, which may occur over short periods, to continental drift and plate tectonics, in which the most recent continental movements have occurred over the last 200-230 million years.

To indicate the dynamic character of biogeography, we need only consider the recent history of the subject, and the impact of the theory of continental drift on biogeography. The concept of a plastic mantle for the earth, plate tectonics, and continents moving, carried on the plates was only developed during the 20th century. The theory was initially proposed by Wegener in 1912. As recently as 1957 there is clear evidence that theory had not been widely assimilated and accepted. One of the leading biogeographers of the 20th century, Philip Darlington rejected the concept of continental drift in the first version (1957) of his classic book. Other biogeographers, as well as Darlington in a revised edition (1965), rewrote ideas about explanations to include the impact of continental drift. Today, no biogeographer questions the impact of drift.

Similarly, we can look back to Darwin to appreciate his recognition of islands as important natural experiments in ecology and evolution. However, island biogeography was initially viewed as an interesting sidelight to larger problems of continental distribution. Now island processes are seen as important in understanding the population dynamics and genetics of species having patchy distributions, which, at one scale or another, characterizes the distributions of almost all species. Islands are now seen to include situations as diverse as oceanic or fresh water islands or lakes in a terrestrial matrix, habitat islands, peninsulas, woodlots, clumps of zebra mussels on lakebeds of the Great Lakes, and even patches in the abundance distribution of species scattered widely over an area. Lake Huron is an aquatic island on the North American continent, Manitoulin Island is an island in Lake Huron, and lakes are biological islands on Manitoulin Island. Island concepts are also important in considering how best to preserve species and communities as humans impose themselves on natural environments. We can trace the recognition of the broad importance of islands to important publications by Robert MacArthur (1963) and Edward Wilson (in 1967).

The theory of island biogeography is a critical component in the design of natural preserves and in assessing the likelihood (or time) of persistence for endangered populations. However, even as it is indicated as important, it should also be recognized that aspects of the theory are still very contentious. There was an extensive literature, mostly from the early 1980's, arguing whether the statistical tests of observations based on the model, particularly occupancy and coexistence on islands, were correct. Dan Simberloff argued that appropriate null hypotheses, against which to test observations and model predictions, had not been formulated. Related arguments about whether communities are random assemblages from pools of potential colonists, or whether there are discernable assembly rules that can predict which species (or at least species from particular ecological groups) will be represented together in established communities. Some aspects of biogeography remain highly relevant to conservation programs today, although the same issues can be addressed through studies of sub-divided populations, called metapopulations.

An Historical Perspective

The science of biogeography can only realistically have begun when its students got past simply describing and naming new species, and into describing habitat characteristics and relationships among species (e.g. competition, predation, mutualism), dispersal capabilities in relation to geological events, climate and climate change, and continental drift. That is not an exhaustive list, but fairly inclusive. The first attempts at this sort of analysis are traceable to phytogeography in the first two decades of the 19th century. In 1805 Alexander von Humboldt developed quantitative indicators of relationships between plant species and climate, indicating an initial subdivision of climate types. Humboldt made extensive collections of plants and associated environmental variables throughout Latin America during a 5 year research trip, from tropical forests to Peruvian alpine communities. That first classification was rapidly developed further, particularly by DeCandolle in 1813, but summarized more thoroughly in Candolle (1855).

Not long afterward, first Lyell, then Darwin and Wallace, turned the world of geology, biology and biogeography on its collective ear. Lyell proposed gradual change in the geographical features of the earth. In the process, he developed the concept of uniformatarianism, the idea that processes today are identical to processes operating in the past. It is that concept that allows us to infer history from observations made in contemporary time. If the forces were different, then science, and certainly biogeography, would make little progress. Uniformatarianism does not state that the way things are happening now is identical to the way they happened in the past, but rather that the forces or processes that determine pattern today are identical to the processes which drove changes in the past. Darwin and Wallace, in their separate collecting trips in the new world and southeast Asia respectively, observed species distributions which were critical to the development of the theory of evolution. Darwin noted the presence of shells of marine gastropods high in the Andes in southern Argentina and Chile, and recognized that these areas must once have been marine for shells to be found there. That is, a significant proportion of his information was biogeographical. One of the results of the revision in biological thought caused by the theory of evolution was a parallel revision in biogeography, which could be argued to begin with the works of Ernst Haeckel. He named a special discipline called chorology, which was the study of the spatial distributions of organisms and their causes. One of the major components explaining the change in species' distributions was evolution, and we now call the subject biogeography, which he called chorology.

We all know that one of the driving forces which caused Darwin to publish his theory was the parallel development of a nearly identical theory by Alfred Russell Wallace. Darwin is regarded as the father of the theory of evolution, but both men made very substantial contributions. Wallace and Darwin differed in their beliefs concerning the forces which drove evolutionary change. We know Darwin's belief about biological interactions driving evolution. Wallace felt that abiotic forces were of great importance. One probable reason is differences in the organisms whose evolution was studied. Wallace made his observations mostly on insects, which are more likely to be affected by climatic change or difference. Both Darwin and Wallace made numerous further contributions, but Wallace is regarded as the father of zoogeography. Because animals are mobile, and because so long was spent simply categorizing insects (because there are so many), 'animal biogeography' took longer to get off the ground. The earliest, still valuable animal biogeography is Wallace's master work, The Geographical Distribution of Animals. In it Wallace described the transition in terrestrial fauna between Australia, with its associated islands, and the islands extending out from southeast Asia towards Australia. The exchange of fauna (excepting animals capable of flight or transferred by man) is extremely limited. Two lines have since been drawn by later biogeographers to demark this transition. Weber's line encloses the region in which the mammalian fauna is exclusively Australasian, and west of the Celebes, between Bali and Lompok, is Wallace's line, which marks the outer limit of the Asian (or Oriental) mammalian fauna. In the narrow zone between these boundaries there is limited mixing; the area is called Wallacea.

It could be argued that the 60-70 years following Wallace's zoogeographic work represented a period of consolidation, of data gathering, which was the basis for the radical developments of the last 20-30 years. That, however, would miss various important contributions which occurred in the late 19th and earlier 20th centuries. Among these are included:

1. Bergmann's rule which states that warm blooded animals from cooler climates have larger body sizes and lower surface to volume ratios. That change in body plan is clearly adaptive to restrict heat loss in cooler climes, and to maximize heat dissipation in warmer areas. A good comparison to indicate the difference is to compare the body form of arctic hares (larger bodies, generally 'more spherical') with those of temperate cottontails or jackrabbits (smaller bodies, on average 'longer and leaner').
2. Allen's rule which says that warm blooded animals will have more compact extremities in cold climates than warm ones. The underlying reasoning is the same, i.e. optimization of design for heat dissipation in relation to climate. Following the same comparisons, limbs and ears are shorter in the arctic hare, longer and thinner in the cottontail, and notably long in the jackrabbit.
3. Merriam's classification of altitudinal and latitudinal vegetation types and zones, termed life zones, and their relationship to temperature and rainfall. Most modern diagrams of Merriam's zonation present it as a three axis system, in which the climatic axis is potential evapotranspiration. This represented an advance on the

earlier plant biogeography. Merriam attempted to generalize his classification scheme to animals, and failed.

Finally, we come to the quantitative theory of biogeography, traceable to the monograph by MacArthur and Wilson. While controversies have since developed about the breadth with which the basic theory can be applied, much of its basic structure deserves the same comment that Huxley made upon reading Darwin's The Origin of Species: "stupid of me not to think of that myself".

The history of conservation biology parallels that of biogeography to at least the degree that they overlap. There are unique aspects, however. In this case we are interested in the history of extinctions and the recognition of human impact. Humans (native Americans and Inuit) are widely regarded as responsible for the extinction of a variety of large mammals in North America including mastodons, tapirs, glyptodonts, and giant ground sloths. Humans have long cut forests. In Greek times, the forests of the Baltic area and those in southern Asia were cut for ship building. Tropical forest has been cut for centuries in the course of slash and burn agriculture. When one patch used for subsistence agriculture gave out, a farmer moved to a nearby patch, cut the trees down, then burned the logs, releasing the nutrients tied up in the biomass. Until the soil hardened (laterization) and nutrients percolated down or washed away, the farmer used the patch. When yield dropped, he moved on again. The contemporary problem is the effect of increased population size, meaning larger areas cut and more frequent exhaustion of areas, combined with other impacts mentioned earlier.

There are some common themes. One of the most important is the 'tragedy of the commons'. If everyone takes advantage of common, public areas, each thinking his or her small impact is not important, the summed result is the destruction of the commons. Garrett Hardin, in one of the seminal papers of conservation ethics, wrote about the occurrence of exactly this phenomenon in the commons of New England towns, where grazing one extra cow was thought to be insignificant. The same thing happened in Europe, where royal preserves and the manor lands of the wealthy were unavailable, and the public lands (the commons) were deforested to provide charcoal for heating and industry. There the industrial revolution was the last straw, and Great Britain was largely deforested by the end of the 18th century. It is not that the conservation ethic has not been recognized for far longer than the discipline has existed; it is that scientific efforts to develop a framework for broad principles of conservation have only developed recently.

Conservation biology is a much newer discipline than biogeography. It is always difficult to set a time of origin for something as abstract as a discipline, but the best guess would be to say that conservation biology came into existence as a distinct discipline with the recognition in the 1970's that the rate of extinction of species globally, partially to largely due to the influence of human activities and population growth, is now high enough to parallel rates which were previously only 'seen' during some of the megafaunal extinctions of the past. Therefore, conservation biologists describe the current scenario as a "biodiversity crisis". The rates they quote are almost certainly conservative and lower than actual rates of species loss. The reason is that the areas of greatest diversity, e.g. tropical rain forest and coral reefs, are also areas with the greatest numbers of as yet undescribed species and simultaneously areas under severe pressure from human activities. Tropical rain forest is being cut for fuel wood, lumber, and conversion to pasture land at a rate which will lead to the elimination of all but small protected reserves within about the next 50 years. Coral reefs are affected by physical and chemical degradation due to human activities on nearby terrestrial areas.

Conservation biology is a synthetic science, built from ecology, population biology, population genetics, biogeography, economics, anthropology, philosophy, and probably other disciplines with the intention of developing principles and strategies to preserve diversity. Different approaches may attempt to maintain the diversity of species directly, or through maintenance of a diversity of habitats. It must maintain a balance between the potential desire to preserve everything in a pristine natural state, and the political desire to permit intensive development. The buzzwords among those who work hardest at rational balance are "sustainable development", though there is not yet an established theoretical basis for it.

The main objectives of Conservation Biology are to:

- Investigate human impacts on global diversity
- Develop practical approaches to promote human development without extinguishing biological diversity.

Conservation Biology

- Human population growth has accelerated during the past 400 years, and 100 years in particular; and resource demands have risen accordingly;
- Present threats to biodiversity are unprecedented; never in human history have so many species and habitats been threatened;
- Many of the threats to biodiversity are synergistic (additively or multiplicatively)
  - o e.g. eutrophication (i.e. nutrient enrichment) and overfishing;
  - o e.g. species invasion and climate change (e.g. malaria in North America)
  - o species invasion and overharvesting: e.g. extinction on Feb. 1, 1996 of Polynesian tree snail (*Partula partula*). This species succumbed to combined pressures of human exploitation of its pretty shells, and a nonindigenous mollusc predator introduced for biocontrol of a different species;.
  - o Environmental deterioration may signal pending human misery

1) e.g. history of humans and environmental disaster that occurred on Easter Island (south Pacific)
2) recent history of the Aral Sea. Salinity of this inland 'sea' has increased tremendously as humans appropriated

(diverted) water inflows for agriculture irrigation purposes. As the basin's surface area and volume have declined, it has become increasingly inhospitable to human usage (e.g. as a source of fish).

Conservation Biology is a very new discipline; its most prominent journal Conservation Biology was created in only 1987 and the Society for Conservation Biology (created by Michael Soulé, Paul Ehrlich and Jared Diamond) was founded in 1985. The society has grown explosively since then.

Basic Principles of Conservation Biology:

- Evolutionary change in natural and desirable.
- The ecological world is dynamic and non-equilibrial
- Human presence must be incorporated into conservation planning since we are the major drivers of change.

These principles are largely an offshoot of the statement by the famous ecologist G.E. Hutchinson in which he stressed the 'ecological theater and the evolutionary play'. Ecological events help shape evolutionary patterns of species and communities; in order that evolution be permitted to occur more or less unencumbered, we must not destroy the habitats and species that facilitate evolution.

Richard Primack (1994) has also established basic principles:

- Diversity of organisms is good; humans generally value and appreciate biodiversity, hence the establishment of zoos and botanical gardens.
- Human-mediated extinction of populations and species is bad.
- Ecological complexity is good and in many instances mandatory to species survival; this principle is best exemplified by consideration of the many coevolutionary relationships that exist among species. Harm to one species may result in 'cascading' effects on others.
- Evolution is good.
- Biological diversity has intrinsic value.

SOILS, SLOPES, AND DISTURBING AGENCIES

Soil and substrate influence animals and plants, both at the level of individual species and at the level of communities.

Microbes and Substrate

Acid-loving microbes (acidophiles) prosper in environments with a pH below 5. *Sulfolobus acidocaldarius,* as well as liking it hot, also likes it acid. Alkali-loving microbes (alkaliphiles) prefer an environment with a pH above 9. *Natronobacterium gregoryi* lives in soda lakes. Salt-loving microbes live in intensely saline environments. They survive by producing large amounts of internal solutes that prevents rapid dehydration in a salty medium. An example is *Halobacterium salinarium*.

Plants and Substrate

Plants seem capable of adapting to the harshest of substrates. Saxicolous vegetation grows on cliffs, rocks, and screes, some species preferring rock crevices (chasmophytes), others favouring small ledges where detritus and humus have collected (chomophytes). In the Peak District of Derbyshire, England, maidenhair spleenwort *(Asplenium trichomanes)* is a common chasmophyte and the wallflower *(Cheiranthus cheiri)* is a common and colourful chomophyte. Perhaps the most extreme adaptation to a harsh environment is seen in the mesquite trees (*Prosopis tamarugo* and *Prosopis alba*) that grow in the Pampa del Tamagural, a closed basin, or salar, in the rainless region of the Atacama Desert, Chile. These plants manage to survive on concrete-like carbonate surfaces. Their leaves abscise (are shed) and accumulate to depths of 45 cm. Because there is virtually no surface water, the leaves do not decompose and nitrogen is not incorporated back into the soil for recycling by plants. The thick, crystalline pan of carbonate salts prevents roots from growing into the litter. To survive, the trees have roots that fix nitrogen in moist subsurface layers, and extract moisture and nutrients from groundwater at depths of 6-8 m or more through a tap root and a mesh of fine roots lying between 50 and 200 cm below the salt crust. A unique feature of this ecosystem is the lack of nitrogen cycling.

Calcicoles (or calciphiles) are plants that favour such calcium-rich rocks as chalk and limestone. Calcicolous species often grow only on soil formed in chalk or limestone. An example from England, Wales, and Scotland is the meadow oat-grass *(Helictotrichon pratense),* the distribution of which picks out the areas of chalk and limestone and the calcium-rich schists of the Scottish Highlands. Other examples are traveller's joy *(Clematis vitalba),* the spindle tree *(Euonymus europaeus),* and the common rock-rose *(Helianthemum nummularium).* Calcifuges (or calciphobes) avoid calcium-rich soils, preferring instead acidic soils developed on rocks deficient in calcium. An example is the wavy hair-grass *(Deschampsia flexuosa)*. However, many calcifuges are seldom entirely restricted to exposures of acidic rocks. In the limestone Pennine dales, the wavy hair-grass can be found growing alongside meadow oat-grass. Neutrophiles are acidity 'middle-of-the-roaders'. They tend to grow in the range pH 5-7. In the Pennine dales, strongly growing, highly competitive grasses that make heavy demands on water and nutrient stores are the most common neutrophiles.

Animals and Substrate

Some animals are affected by soil and substrate. For instance, the type and texture of soil or substrate is critical to two kinds of mammals: those that seek diurnal refuge in burrows, and those that have modes of locomotion suited to relatively rough surfaces. Burrowing species, which tend to be small, may be confined to a particular kind of soil. For instance, many desert rodents display marked preferences for certain substrates. In most deserts, no single species of rodent is found on all substrates; and some species occupy only one substrate. Four species of pocket mice *(Perognathus)* live in Nevada, United States. Their preferences for soil types are largely complementary: one lives on fairly firm soils of slightly sloping valley margins; the second is restricted to slopes where stones and cobbles are scattered and partly embedded in the ground; the third is associated with the fine, silty soil of the bottomland; and the fourth, a substrate generalist, can survive on a variety of soil types.

Saxicolous species grow in, or live among, rocks. Some woodrats *(Neotoma)* build their homes exclusively in cliffs or steep rocky outcrops. The dwarf shrew *(Sorex nanus)* seems confined to rocky areas in alpine and subalpine environments. Even some saltatorial species are adapted to life on rocks. The Australian rock wallabies (*Petrogale* and *Petrodorcas*) leap adroitly among rocks. They are aided in this by traction-increasing granular patterns on the soles of their hind feet. Rocky Mountain pikas *(Ochotona princeps)* in the southern Rocky Mountains, United States, normally live on talus or extensive piles of gravel. Those living near Bodie, a ghost town in the Sierra Nevada, utilize tailings of abandoned gold mines. The yellow-bellied marmot *(Marmota flaviventris)* is another saxicolous species, and commonly occurs with the Rocky Mountain pika. The entire life style of African rock hyraxes *(Heterohyrax, Procavia)* is built around their occupancy of rock piles and cliffs. Most of their food consists of plants growing among, or very close by, rocks. Their social system is bonded by the scent of urine and faeces on the rocks. The rocks provide useful vantage points to keep an eye out for predators, hiding places, and an economical means of conserving energy.

Pedobiomes

Within zonobiomes, there are areas of intrazonal and azonal soils that, in some cases, support a distinctive vegetation. These non-zonal vegetation communities are pedobiomes. Several different pedobiomes are distinguished on the basis of soil type: lithobiomes on stony soil, psammobiomes on sandy soil, halobiomes on salty soil, helobiomes in marshes, hydrobiomes on waterlogged soil, peinobiomes on nutrient-poor soils, and amphibiomes on soils that are flooded only part of the time. Pedobiomes commonly form a mosaic of small areas and are found in all zonobiomes.

There are instances where pedobiomes are extensive: the Sudd marshes on the White Nile, which cover 150,000 km^2; fluvioglacial sandy plains; and the nutrient poor soils of the Campos Cerrados in Brazil.

A striking example of a lithobiome is found on serpentine. The rock serpentine and its relatives, the serpentinites, are deficient in aluminium. This leads to slow rates of clay formation, which explains the characteristic features of soils formed on serpentinites: they are high erodible, shallow, and stock few nutrients. These peculiar features have an eye-catching influence on vegetation. Outcrops of serpentine support small islands of brush and bare ground in a sea of forest and grassland. These islands are populated by native floras with many endemic species.

GENESIS OF SOIL

Soils of the coastal areas present generally little evolution, since they are affected by erosional-depositional events, oscillating water-table, spatial variability of texture, carbonate and organic matter content. Leaching, decarbonation, brunification, gleyzation have been recognised as the most active soil forming processes in these areas in temperate regions. Also anthropic intervention contributes in modifying soil development: sand and water extraction, terrain levelling, tourism enhancing, land use changing, all of these contribute to new environmental conditions that may affect pedogenesis. Correspondingly, the natural vegetation of these areas may be subjected to change with changing of environmental conditions.

Similar modifications have been recorded recently in coastal and wetland areas of North-East Italy, where land reclamation and changes in management in the last 100 years determined new conditions for the soil genesis and the development of the vegetation cover.

The objectives of this work were:

- To examine the soil distribution in these sensitive areas, which constitute examples of pedosites subject to disappear with changing of environmental conditions;
- To relate soils and phytocoenoses with peculiar ecological characteristics; and
- To indicate a trend of pedogenesis which might be applied to areas subjected to watertable or sea level variations, in

consequence of hypothetical climatic changes and in relation to their future management.

Materials and Methods

Site Location

The investigated area is part of the perilagoonal belt located in the northeastern part of Italy, between the river Isonzo and the Venice lagoon. Geologically, it is composed of Holocene mainly sandy alluvial materials. All over the Holocene, the coastline was close to the present. However, subsidence, eustatism and variations in river-transported solid materials determined a peculiar topography, with depressed wetlands and hydromorphic areas alternating with drier ones, located in more elevated places.

Data elaboration on the basis of the bioclimatic indexes proposed by Rivas-Martinez et al. shows that the present climate in the study area is temperate submediterranean subhumid. The mean annual temperature is 14°C. Mean annual precipitation ranges from about 950mm in the southern part and 1,035mm in the northern part. The Soil Taxonomy, the calculated Soil Temperature Regime is mesic; and Soil Moisture Regime is variable from aquic to udic-xeric depending on local topographical conditions.

The vegetation of the area is characterised by the mutual influence of different chorologic elements: C-European, Mediterranean, Orophilous and Illyric. Such a compenetration, together with the peculiar environmental conditions, is responsible for the coexistence of plant communities with both a C-European and Mediterranean trend. At the same time, the local topography determines the presence of the edaphoxerophilous series at some sites, and the edaphohygrophilous one at other ones.

Among the different phytocoenoses in the investigated area, the most interesting are the hygrophilous natural and semi-natural fens and meadows, like the endemics Erucastro-Schoenetum nigricantis and Plantagini altissimae-Molinietum caeruleae, growing on neutral to subalkaline soils enriched in organic matter. The latter association is common in areas where water-table is close to the surface, and the continuous agricultural management enhances preservation of these prairies. Progressive abandonment determines littering, auto-manuring and development of common shrubs, and successively wood vegetation.

THE EFFECTS OF CLIMATE CHANGE ON ECOSYSTEMS

One way that scientists gain understanding of how global warming will affect ecosystems is to analyse the effects of past climate on paleoecosystems.

A paleoecosystem is an ecosystem that existed in a former geologic time period. By relating vegetative cover to past climates, models can be developed.

Once a reliable model is created, input variables such as CO_2 can be varied and the results analysed. An example of what the effect would be like on populations of Douglas fir in the northwestern United States if the CO_2 content in the atmosphere were double what it was before the Industrial Revolution was modeled by the U.S. Geological Survey and is shown in the illustration that follows.

In a study conducted by the U.S. Global Change Research Programme in Washington, D.C., first in 2001, then updated in 2004, in trying to predict what the effects of future climate change would have on ecosystems, they concluded that"climate change has the potential to affect the structure, function, and regional distribution of ecosystems, and thereby affect the goods and services they provide." They based their conclusions on a modeling and analysis project they conducted called the Vegetation/Ecosystem Modeling and Analysis Project.

This project was used to generate future ecosystem scenarios for the conterminous United States based on model-simulated responses to both the Canadian and Hadley scenarios of climate change. The VEMAP was subsequently used in a validation exercise for a Dynamic Global Vegetation Model by Oregon State University and the U.S. Forest Service in 2008. Their MC1-DGVM was used as the input data in both the VEMAP and VINCERA. Their MC1 was run on both the VEMAP and VINCERA climate and soil input data to document how a change in the inputs can affect model outcome.

The simulation results under the two sets of future climate scenarios were compared to see how different inputs can affect vegetation distribution and carbon budget projections.

The results indicated that"under all future scenarios, the interior west of the United States becomes woodier as warmer temperatures and available moisture allow trees to get established in grasslands areas.

Concurrently, warmer and drier weather causes the eastern deciduous and mixed forests to shift to a more open canopy woodland or savannatype while boreal forests disappear almost entirely from the Great Lakes area by the end of the 21st century. While under VEMAP scenarios the model simulated large increases in carbon storage in a future woodier west, the drier VINCERA scenarios accounted for large carbon losses in the east and only moderate gains in the west.

But under all future climate scenarios, the total area burned by wildfires increased." The similarities of the two models served to validate the VEMAP project.

The Hadley model was developed by the Hadley Centre for Climate Prediction and Research in England. Also referred to as the Met Office Hadley Centre for Climate Change, it is based at the headquarters of the Met Office in Exeter. It is the key institution in the United Kingdom for climate research. It is currently involved not only with understanding the physical, chemical, and biological processes within the climate system, but also with developing working models to explain current phenomena and to predict future climate change. It also monitors global and national climate variability and change and strives to determine the causes of the fluctuations. The Canadian climate model was developed by the Canadian Centre for Climate Modelling and Analysis. The CCCma is a division of the Climate Research Branch of Environment Canada based out of the University of Victoria, Victoria, British Columbia.

Its specific focus is on climate change and modeling. In the past nine years, the CCCma has produced three atmospheric and three atmospheric/oceanic general circulation models, making them one of the international leaders in climate change research.

What they found was that over the next few decades climate change in the United States will most likely lead to increased plant productivity as a result of increasing levels of CO_2 in the atmosphere.

There will also be an increase in terrestrial carbon storage for many parts of the country, especially the areas that become warmer and wetter. The southeast will most likely see reduced productivity and, therefore, a decrease in carbon storage. By the end of the 21st century, many areas of the country will have experienced changes in the distribution of vegetation. Wetter areas will see the growth of more trees; drier areas will have drier soils that will cause forested areas to die off and be replaced by savanna/grassland ecosystems.

Modeling the vegetation evolution and adaptation is more difficult. The study focused on two time periods: 2025-2034 and 2090-2099. In the near term, biogeochemical changes are expected to dominate the ecological responses. Biogeochemical responses include changes based on the natural cycles of carbon, nutrients and water. The responses are affected by changing environmental conditions such as temperature, precipitation, solar radiation, soil texture, and atmospheric CO_2.

It is these natural cycles that affect carbon capture by plants with photosynthesis, soil nitrogen processes, and water transfer. These biogeochemical factors are what influence the production of vegetation. In the results from the near-term biogeochemical model, the scientists concluded that there would be an increase in CO_2. They estimate that currently the average carbon storage rate is 66/Tg/yr. The Hadley model predicted that carbon storage rates by 2025-2034 would increase to 117/Tg/yr.

The Canadian model estimated CO_2 to increase 96 Tg/yr. The Canadian model projected that the southeastern ecosystems will lose carbon in the near term because they predict the climate there will become hot and dry.

The biogeography models look at the changing landscape based on changes in CO2, evapotranspiration, vegetation establishment, and competition between species, growth rates, and life cycle/mortality rates. In this model, scientists at both the Hadley and Canadian Centre for Climate Change agree that vegetation will be able to freely move from one location to another.

Changes in vegetation distribution will vary from region to region as follows:

- *Northeast*: Forests remain the dominant natural vegetation, but forest mixes will change. There will also be some increase in savannas and wetlands.
- *Southeast*: Forests remain the dominant ecosystem, but mixes change. Savannas and grasslands encroach on forests, especially towards the end of the 21st century. Drought and wildfires contribute significantly to forest destruction.
- *Midwest*: Forests remain the dominant land cover, but changes in species type occur. There will be a modest expansion of savannas and grasslands.
- *Great Plains*: Slight increase in woody vegetation.
- *Wes*t: The areas of desert ecosystems shrink, and forest ecosystems grow.
- *Northwest*: Forested areas grow slightly.

A separate study conducted by the Canadian government predicts the following ecosystem changes as a result of changing climate over the next 100 years:

- *Coastlines*:
  - Flooding and erosion in coastal regions
  - Sea-level rise
- *Forests*:
  - Increase in pests
  - Increased levels of drought and wildfire

- *Plants and animals*:
  - Warmer temperatures could make water supplies more scarce, having a negative impact on plants and animals, not giving them time to adjust.
- *Crops*:
  - In some areas, warmer climate may allow a three- to five-week extension of the frost-free season, which could benefit commercial agriculture.
  - In other areas, drier soils and lack of water will have a negative impact on agricultural productivity.
- *Wells*:
  - The quality and quantity of drinking water may be threatened by increasing drought.
- Harsh weather:
  - Winter storms, floods, drought, heat waves, and tornadoes could become more frequent and severe.
- *Fisheries*:
  - Populations and ranges of species sensitive to changes in water temperature will be negatively affected.
  - Salmon harvests will be lower in the Pacific.
  - Changes in ocean currents may have a negative impact on the fisheries in the Atlantic.
- *Lakes and rivers*:
  - Water levels will decline under the influence of drought, negatively affecting drinking water quality.
  - Use of lakes for transportation, recreation, and fishing, and the ability to generate electricity may be curtailed under droughtlike conditions.
  - Other areas that may have an increase in precipitation may experience flooding, rising sea levels, and severe storms.

In February 2005, the Met Office in Exeter, England, issued a report titled"Avoiding Dangerous Climate Change." The objective of the study was to determine what levels of CO_2 were considered the tipping point for dangerous climate change with harmful effects on ecosystems and what actions could be taken now to avoid such an outcome. In the report, then prime minister Tony Blair stated:"It is now plain that the emission of greenhouse gases... is causing global warming at a rate that is unsustainable."

Environment Secretary Margaret Beckett stated,"The report's conclusions would be a shock to many people.The thing that is perhaps not so familiar to members of the public... is this notion that we could come to a tipping point where change could be irreversible. We're not talking about it happening over five minutes, of course, maybe over a thousand years, but it's the irreversibility that I think brings it home to people."

The report, published by the British government, says there is only a small chance of greenhouse gas emissions being kept below"dangerous" levels. It warns that the Greenland ice sheet could melt, causing sea levels to rise by 23 feet over the next 1,000 years. It also warns that developing countries will be the hardest hit. The report also states, based on the vulnerability of many of the world's ecosystems, that the European Union (EU) has adopted a target of preventing an increase in global temperature of more than 3.3°F (2°C). Some believe even that may be too high. The report states:"Above two degrees, the risks increase very substantially," with"potentially large numbers of extinctions" and"major increases in hunger and water shortage risks... particularly in developing countries." In order to meet their goals, British scientists have advised that CO_2 levels should be stabilized at 450 parts per million (ppm) or below. Currently the atmosphere contains 380 ppm. In response to this, the British government's chief scientific adviser, Sir David King, said that was unlikely to happen. He stated,"We're going to be at 400 ppm in 10 years' time. I predict that without any delight in saying it." Myles Allen, an expert on atmospheric physics at Oxford University, said that:"Assessing a 'safe level' of carbon dioxide in the atmosphere was 'a bit like asking a doctor what's a safe number of cigarettes to smoke per day.'"

The report does conclude, however, that there are technological options available to reduce CO_2 emissions that will need to be used. The study also concluded that the biggest obstacles involved with using these new technologies, along with renewable resources of energy and"clean coal," are the current economic investments and traditionally strong bond to the oil industry, cultural attitudes that oppose change, and simple lack of awareness by many people.

Various conservation organizations currently involved in the battle against global warming, such as the Union of Concerned Scientists (UCS), the Defenders of Wildlife, and the World Wildlife Fund (WWF), also support these ideas.

2

Biogeography Processes in Bioclimatic Zones and Biomes

UNDERSTANDING THE BIOGEOGRAPHY

Biogeography is a branch of geography that studies the past and present distribution of the world's many species. It is usually considered to be a part of physical geography as it often relates to the examination of the physical environment and how it affects species and shaped their distribution across space. As such it studies the world's biomes and taxonomy—the naming of species. In addition, biogeography has strong ties to biology, ecology, evolution studies, climatology, and soil science.

History of Biogeography

The study of biogeography gained popularity with the work of Alfred Russel Wallace in the mid-to-late 19th Century. Wallace, originally from England, was a naturalist, explorer, geographer, anthropologist, and biologist. He first extensively studied the Amazon River and then the Malay Archipelago. During his time there, he examined the flora and fauna and came up with the Wallace Line—a line that divides Indonesia apart and the distribution the animals found there. Those closer to Asia were said to be more related to Asian animals while those close to Australia were more related to the Australian animals. Because of his extensive early research, Wallace is often called the "Father of Biogeography."

Following Wallace were a number of other biogeographers who also studied the distribution of species. Most of those researchers looked at history for explanations, thus making it a descriptive field. In 1967 though, Robert MacArthur and E.O. Wilson published The Theory of Island Biogeography. Their book changed the way biogeographers looked at species and made the study of the environmental features of that time important to understanding their spatial patterns. As a result, island biogeography and the fragmentation of habitats caused by islands became popular as it was easy to explain plant and animal patterns on islands. The study of habitat fragmentation in biogeography then led to the development of conservation biology and landscape ecology.

EFFECTS OF BIOGEOGRAPHY ON COMMUNITY DIVERSITY

Why do some places contain more species than others? Many patterns in the spatial distribution of species have been identified by biogeographers, and many mechanisms have been proposed to explain these patterns. A species occurs in a given place and time because members of this species (or its ancestors) evolved in this location or dispersed to it at some point in the past. Biogeographers seek to discover new patterns in the distribution of species across space and use diverse research methods to study the historical and ecological factors that can explain these patterns.

Some places contain more species than others. For example, Antarctica has fewer species than a temperate deciduous forest, which in turn has fewer species a tropical rainforest. For over 150 years, researchers have sought to make sense of the gross and fine scale spatial patterns in biodiversity, and to elucidate both the proximate and ultimate causes for these patterns.

This chapter describes some of the major geographic patterns in species richness, and the processes and theories that are thought to account for these patterns. Much of this knowledge has emerged from the tremendous body of work from one scientist, Alfred Russel Wallace, widely regarded as the "Father of Biogeography."

Aside from co-originating the process of Natural Selection with Charles Darwin, Wallace spent extended periods studying the distribution and diversity of plants and animals in Amazonia and Southeast Asia in the mid 1800s. Many of the patterns and processes featured in this chapter were initially described by Wallace, and careful study of his work indicates that his ideas presaged many of the discoveries made by his numerous successors.

Many of the spatial patterns in biodiversity are overt, others are subtle and yet additional patterns remain undetected. While the existence of these patterns may be obvious — and changes in the environment that are paired with these patterns may also be obvious — the mechanisms that cause the differences in biodiversity along environmental gradients are under still the subject of scientific debate. Because large-scale patterns are the emergent result of complex interactions at many spatial and temporal scales, no single answer is likely to ever emerge, but with continued research our understanding of the processes shaping these patterns increases.

Historical Processes Affecting Biogeography

All species occurring in at a given place and time either arrived from another place or originated in that location from ancestral species. This fact applies to extinct species that were ancestors of all extant species. Species richness in a given location is the result of three factors — the rate of speciation, the rate of extinction, and the dispersal of species from other locations. In principle, if biogeographers could understand how the current and past environment has shaped these three factors, we would then obtain a comprehensive understanding of what generates all biogeographic patterns of species richness. However, numerous environmental and organismal parameters can drive these historical factors, in both complex and interacting fashions.

The study of historical factors shaping species richness and distribution is often broken into two major categories: vicariance and disperal. Species can occur in a location because their ancestors remained there passively as the environment moved around them (vicariance). Alternatively, a species or its ancestors may have arrived at a location via movement from another location (dispersal). Vicariance describes the disruption of the biogeographic range of a group of organisms by changes in the environment. Vicariant events can happen when landmasses move apart through tectonic action, or when mountains emerge to divide the geographic ranges of species. Vicarance typically leads to the emergence of new species through allopatric speciation, in which one ancestral species will result in the production of two new species that evolve apart from one another in geographic isolation, frequently by genetic drift rather than natural selection. Dispersal biogeography focuses on the movement of species from one location to another location. Jump dispersal events, when individuals of a species travel a relatively long distance to a new environment in which they did not previously occur, can result in the adaptive radiation of one ancestral species giving rise to a broad diversity of new species. Classic examples of adaptive radiation include fruit flies in the Hawaiian Islands, finches on the Galapagos Islands, and anolis lizards throughout Central and South America and the Caribbean. Both the Galapagos and Hawaiian islands emerged from the sea floor in the ocean and all species occurring on such oceanic islands needed to arrive via dispersal, whereas continental islands which broke off from a mainland may contain species as a result of vicariance.

Major Spatial Patterns in Biodiversity

One major geographic pattern in biodiversity is the latitudinal gradient in species richness. As one travels further away from the equator, for most taxa, the number of species declines. For example, demonstrates the latitudinal richness gradient for richness in ants of the Northern Hemisphere. This general pattern holds true for most taxa and ecosystem types in both marine and terrestrial environments. There is broad agreement that this pattern is caused by differences in the abiotic, climatic environment, but the specific mechanism or mechanisms causing this pattern are a continued topic of discussion and investigation. One set of theories, broadly grouped together as "species-energy theory" is based on the fact that the amount of radiant energy from the sun captured by ecosystems is negatively associated with latitude. As energy is distributed throughout ecosystems through trophic processes, it is thought that species richness will track the energy following one or more mechanisms. Models of species-energy theory incorporate variables such as temperature, net primary productivity, speciation, and extinction. Other ideas that have been proposed to account for the latitudinal gradient are related to the physiological responses of animals to climatic conditions and the effects of the abiotic environment on historical processes. Most of these theories are not mutually exclusive.

The maximum number of genera sampled decreases as one moves north from the equator.

Another recurring pattern in biogeographic theory is the elevational gradient in species richness. As one travels to higher elevations, the number of species declines, or, in many cases, peaks at mid-elevations. Aside from the environmental mechanisms driving this diversity gradient, there is a phenomenon that is based on the geography of species range distributions called the mid-domain effect. The mid-domain effect predicts a peak of diversity at the midpoint along any domain simply by the fact that the ranges of more species overlap in the middle of a domain (like a mountain or an island) than on the edges, and this effect works together with environmental determinants to affect the net distribution of species along many elevational gradients.

A third recurring pattern in the distribution of species is the area effect on species richness. The larger an place is, the more species it can support. This applies to actual islands in bodies of water, as well as habitat islands such as those surrounded by human development.

Do Neutral Models Explain Patterns in Species Richness?

So far, we have discussed biodiversity in terms of species richness but not whether the properties of the species in a location are related to the level of species richness. Are all species at a given trophic level interchangeable, in terms of their effects on overall species richness? A number of neutral models (such as the theory of island biogeography) do not consider the specific ecological interactions of members of a community. In other words, a neutral theory of biodiversity does not consider differences in the niches of any species at a given trophic position. Under neutral models, differences in relative abundance of any species are caused by historic patterns of abundance and dispersion, and not by the traits of any given species. Even if the niches of two species are demonstrably distinct, then under neutral models these species have equal effects on biodiversity. Neutral models may turn out to serve as effective null models for community assembly, just as Hardy-Weinberg models have served for population genetics. They also allow explicit modeling to test competing models for large-scale patterns in biodiversity.

We have also talked about large-scale effects on diversity — such as climate and area, but do local interactions – like competition and predation — influence the distribution of biodiversity? The fact that some species have greater effects on species richness than others may be gleaned from studying the biology of invasive species. An invasive species is one which is transported outside its original geographic range to a novel habitat, where it increases in density, and can cause detrimental effects on the indigenous species in that area, often reducing biodiversity. One example of an invasive species is the Argentine ant (*Linepithema humile*); more than 100 years ago this species was transported from Argentina to most other biogeographic regions, and where this species occurs the local species of other ants is markedly reduced. Another example of an invasive species with negative effects on native faunas are cane toads (*Rhinella marina*) introduced from the Neotropics into Australia in 1935. Cane toads have reduced prey availability for indigenous predators and caused declines in native Australian amphibians. Most introduced species do not become invasive, indeed they frequently become extinct because they are less likely to be well adapted to the new environment than indigenous species, but the subset of introduced species that become invasive is problematic in terms of the economy, ecosystem services, and biodiversity. The widespread exchange of species among distant parts of the world as a result of human commerce has clearly resulted in a loss of biodiversity at many spatial scales.

Summary

The structure of the world is predictive of the species richness. Factors that predict species richness include the size and position of continentals and islands, the height and position of mountains, and temperature and access to energy from the sun. Moreover, the effects of geography on species richness are not limited to conditions we currently observe, as many of the patterns we observe are contingent on historic movements of land masses and the uplift and erosion of mountains, and the associated effects on climate and the persistence and dispersal of organisms. By studying how richness varies from location to location, we more generally understand its causes and better predict its future.

CHARACTERISTICS OF BIOCLIMATIC ZONES

Climate

There is a temperature gradient from the equator to the poles because of the earth's orientation toward the sun. The rotation of the earth and the inertia of the air above it causes westerly winds at the equator. The Coriolis force deflects winds to the right in the northern hemisphere and to the left in the southern hemisphere, causing wind gyres. Equatorial air rises and, deflected, falls back to the surface in temperate latitudes, where it then flows toward the east. Wind patterns produce major ocean currents revolving counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere in each ocean basin. Current gyres carry cold water toward the equator on east sides of the oceans, warm water to higher latitudes on the west sides. The temperature of water bodies affects nearby land masses greatly, although there is less effect with distance from water. Land masses and underwater topography deflect currents into complex patterns near the continents. These in turn cause upwellings, which affect productivity and thus diversity and abundance of marine organisms, including those such as birds and pinnipeds that are based on land. The wind blows water vapor from the ocean to the land. If the land is hotter, it evaporates; if cooler, it falls as precipitation. As the air ascends and cools, it loses its capacity to hold water (adiabatic cooling). Thus in hot weather thermals rise, and water condenses and falls as showers; also precipitation increases up mountainsides. Mountains serve as barriers to water vapor, causing rain shadows on their leeward sides. The tilting of the earth, with accompanying migration of the thermal equator, causes seasonal changes of wind direction responsible for the seasonality of precipitation patterns in the tropics; precipitation is also affected by the seasons in temperate latitudes.

Soils

Parent rock erodes physically and chemically into smaller and smaller particles, which become soils as they collect on both coarse and fine scales; the chemical nature of soil reflects the nature of its parent rock. Particles are further sorted by size when deposited by water and wind. Soils are classified by the size of the particles that make them up, from the finest (clay) through increasingly coarse (silt, sand) to the coarsest (gravel), and by organic content (humus). Loam is soil that is well mixed with sands, silts and clays. Soils form horizons, layers that are distinct from one another chemically and physically because of their distance from the surface (which in turn controls the amount of water and organic material present). The overall direction of water movement (up or down) through soil is of some importance in determining its structure. The water-holding capacity of soil is related to the soil type, with the finest soils holding water and coarser ones allowing it to percolate through. The value of soil to plants is related to its water-holding capacity, physical nature (what mixture of sand, silt and clay particles), and chemical content; both inorganic minerals and organic humus are important.

Vegetation

Vegetation patterns are responsive to the interaction of temperature (latitudinal and altitudinal gradients) and precipitation (more complex, often longitudinal gradients because of the east-west tendency of the winds, as well as well-defined latitudinal ones) patterns. The degree of seasonality also has a major effect. The earth's surface is forested with trees except where too cold, too dry, or too wet. Herbaceous vegetation is dominant nearer extremes, with no vegetation at all at the coldest and driest extremes.

Vegetation is the sum of its parts, the parts being individual plants of individual species, and the species present and their relative proportions are important descriptive components of it. Descriptions of vegetation take into account plant species and their abundance and size distribution, life forms (trees, shrubs, herbs, bryoids, epiphytes, lianas), seasonal functions (evergreen vs. deciduous), and leaf shapes, sizes, and textures.

Diversity

There are two major components of diversity: within-habitat (diversity may vary greatly between two forest types, for example) and between-habitat (this covers diversity for an entire area, thus also dependent on the diversity of habitats present). Within-habitat diversity is highest in forests of the equatorial lowlands, and lower with increased latitude, altitude, seasonal variation in climate, simplicity of vegetation, and any environmental extreme, to very low near poles and on high mountains. There are similar latitudinal gradients in fresh and salt water, also decreased aquatic diversity with depth and chemical extremes. There is also lowered diversity on peninsulas and islands because of problems of historical access.

Plant Adaptations

The basic needs of plants are homeostasis, space, food, predator avoidance, and reproduction. There is no locomotion, thus plants are subject to vicissitudes of the environment, so they are often narrowly restricted to particular combinations of temperature, humidity, salinity, soil water, and chemistry (where homeostasis is thus assured). Plants need space for branches and stems for support of light-gathering, photosynthetic, and respiratory leaves; elaboration of woody tissue provides greater support for big plants. They also need space underground for roots for gas and chemical exchange with the substrate, and for nutrient and water gathering. Competition for space is intense among plants, at leaf and root level. Plant nutrition comes from a combination of leaf photosynthesis and root gathering. Predator avoidance is by physical (spines, hairs, sticky resins) and/or chemical means (there is an almost infinite number of chemicals in plants that lower their palatability to animals) or even by rarity of the plant, its flowers or fruits.

Reproduction is by flowers and fruits. As locomotion is lacking, reproduction depends on other features of the environment—wind, water, or animal pollination and seed dispersal. Animals are often important for dispersal of pollen and seeds. Reproductive structures vary widely: inflorescence type, flower sizes, shapes and colors; infructescence type, fruit sizes, shapes and colors; seed sizes and numbers. Most of these are clearly correlated with the mode of pollination/seed dispersal.

Animal Adaptations

Animal basic needs include homeostasis, space, refuge, food, predator avoidance, and reproduction. Homeostasis needs lead to occurrence only in a restricted range of temperature, humidity, salinity, oxygen level, and other features that affect the animal's internal environment. There is great variation in tolerance to environmental extremes, maximal in endothermal birds and mammals. Land and water are two basic environments, and many animals move between them or secondarily into the air for relatively brief periods. Locomotion is significant in animals (lacking in plants for most part) to allow these movements, also movement about home range and long-distance movements that may be for dispersal or may involve seasonal back-and-forth migration. Some major groups of animals are sessile (fixed in place) and like plants move only in certain life-history stages. Space needs lead to fixed or dynamic home ranges, which are defended in some sessile or territorial motile animals. The size of the home range or territory may change seasonally or be different in different age/sex classes. Refuges are needed for hiding from predators, sleeping, storing food, and having and rearing young.

Food sources are plants (herbivores) or other animals (carnivores), and diets vary from very generalized to very specialized. Many animals are omnivores (plant and animal diets). Herbivores specialize on leaves, seeds, fruits or nectar, with different arrays of adaptations for each type. Leaves are easy to capture but difficult to digest, so leaf-eaters have special adaptations to process cellulose and antiherbivore compounds. Seeds are locally and seasonally abundant, and are often stored by caching for leaner periods. Special adaptations (rodent teeth, finch bill) are needed to crack seed coats. Color vision is an important adaptation to locate flowers and fruits for both nectar- and fruit-eating, with much coevolutionary fine tuning for these pollinating and seed-dispersing interactions. There are just as many specialized sets of adaptations for carnivory, including those for finding and capturing plankton, mollusks, worms, termites, butterflies, fish, snakes, birds, and other morphologically distinctive taxonomic groups, even carrion. Memory and intelligence are characteristic components of some of these predator adaptations, but there are many other special attributes, such as the use of tools or venom. There are many predator-avoidance adaptations, including hiding out of sight or in sight (camouflage); escaping by speed or stealth or immersion in a group; fighting or threat with weapons (teeth, horns); physical protection such as spines or shells; chemical protection such as unpalatability or poisonous bite or sting; and mimicry of unpalatable/dangerous animals. There is a wide variation in reproductive strategies: clutch size, size of offspring at birth, eggs vs. live birth, and degree of parental care.

Most types of adaptations are clearly attributable to one of these basic needs. For example, coloration may be an adaptation for species recognition (need for conspecific territory defenders to recognize each other involves space; need for mates to recognize one another involves reproduction), to look like the environment (camouflage for predator avoidance or prey capture) or like some other animal (mimicry for predator avoidance) or to warn of its dangerousness (aposematic coloration for predator avoidance) or to increase or decrease heat load by absorbing or reflecting sunlight (homeostasis).

Human Effects

Those that are negative to the environment include habitat destruction, chemical pollution, predator/parasite introduction, competitor introduction, and active persecution for food, skin, sport, etc. Those that are positive to the environment include conservation by habitat preservation and captive breeding. Those that are positive to humans and may or may not be harmful to the environment include animal domestication and horticulture.

ENVIRONMENTAL FEATURES OF COASTAL ZONE

The Natural and Human Setting

The principal settled areas are uniquely dependent on sound environmental management. The coastal plain occupies approximately 7 per cent of the total area of the country and extends along the entire 430 km. of the Atlantic coast, varying in width from 26 to 77 km.

Five major wetland systems are distinguished in the coastal plain: the marine ecosystem of the sea coast, the estuarine ecosystems of tidal wetlands of the river mouths, and the riverain, palustrine and lacustrine ecosystems. The fertile plain consists of surface clays underlain by clays of the Demerara and Coropina formations. Extending for as much as five miles inland, much of the coastal plain lies between 0.5 metres and 1.0 metres below high tide levels. The shore zone consists of coastal works, mud banks, a mangrove belt and sand flats, all of which serve to protect the plain from flooding.

Ninety per cent of the estimated population of 751,000 resides in the coastal zone. Georgetown has a population of approximately 200,000 in its greater metropolitan area. Agriculture is still the major economic activity, accounting for 24 per cent of GDP and 35-40 per cent of employment. Except for forestry, all agricultural products (sugarcane, rice, other crops, livestock, and fishing) come from the coastal area. Most of the industry is found in Georgetown and along the remaining coast, with only a small concentration in Linden and north of Linden along the Demerara river. Other major economic activities and investments outside Georgetown and the coast consist mainly of large and small scale mining, mostly on major rivers. Groundwater provides 90 per cent of the potable water supply and is extracted mainly from the coastal artisan basin.

Complex interlinked erosion and flooding issues threaten the viability of the intensely concentrated economic base. Sea level rise and possible coastal subsidence add to the pressures on the sea defences and, inevitably, lead to greater coastal erosion and flooding. The shorezone, which serves as the natural line of defence against coastal erosion, is subject to erosion from floating mud shoals in the Atlantic that originate in the Amazon, exacerbated by destruction of mangroves and by removal of sand for construction on shore. The system of water conservancies and drainage and irrigation works in the coastal plain, which have also suffered from lack of maintenance, cause periodic fresh water flooding.

Coastal Erosion

Coastal erosion has been taking place at a relatively rapid rate. A comparison of the 1783 and 1970 coastlines around Liliendall shows a regression of almost 1 kilometre (erosion rates of -4 to -5 metres annually). Evidence of this retreat can be seen all along the coast — old sluice gates form isles far out to sea, and old shorelines and sand ridges run parallel to the present shoreline. Coastal erosion has many causes, some natural and some man-made, and distinguishing between the effects of each is difficult given the paucity of baseline data.

Mud shoals have had and continue to have an unquantifiable impact on coastal erosion. These shoals move along the Brazil, Suriname, Guyana coast from east to west in a series of waves and macro ripples at an approximate speed of 1.3 km per year. They are in constant motion and the refraction and concentration of wave energy between ripples greatly increases the capacity of the shoals to erode the coastal area. On the eastern side of the shoal, the coast accumulates the mud that is colonized by mangroves.

However, as the mud shoal moves westward, the mangroves are unable to survive the wave attack and erosion takes place.

Mangroves are a first line of defence against wave action and storms on the coast and also provide a habitat for juvenile fish and shrimp. The construction of drainage systems for agricultural production projects in the coastal zone may have adversely impacted mangroves, as was evident once the MMA-ADA drainage and irrigation scheme was in operation. Mangroves are also plundered for fuelwood and for use in construction and tanning. No clear picture of the extent of the degradation of the mangroves is available, but prudence dictates that they should be protected from further destruction to help prevent further erosion of the coastline and also to preserve the breeding grounds for some marine species.

Sea level rise is another possible cause of coastal erosion. Tide gauge readings in Georgetown from 1960 to 1981 showed a rise of 9 cm. in the relative level of the sea. Engineers in the Hydraulics Division have observed water levels reaching higher up the sea walls. The observed rise in water levels, however, may be partly attributable to subsidence of the coastal zone, caused by the extraction of fresh water from the coastal aquifers. At present the data are inadequate to determine how much of the observed water level rise might be due to subsidence and how much is due to actual sea level rise.

Flooding and its Costs

The coastal plain is subject to flooding from both sea water intrusion and from fresh water overflows. Flooding destroys the value of the country's physical capital and its productivity, e.g., agricultural lands normally remain out of production for at least a year once flooded by saline water. Floods also have serious public health consequences in coastal areas. In Georgetown, sewage is discharged untreated through an outfall into the mouth of the Demerara river and during high tides and flooding this sewage is returned inland. Other areas use septic tanks and pit latrines, which may contribute to pollution of groundwater and, during flooding, surface waters. For the past two decades, lack of maintenance, mainly because of budgetary constraints, has seriously weakened the sea defences. In 1991 more than 25 breaches of the sea wall flooded agricultural and residential areas. One breach at Cornelia on Leguan Island resulted in more than 1,000 acres of rice land being flooded. Since 1993 responsibility for maintenance of the sea defences was transferred from regional authorities to the Hydraulics Division, but the pervasive lack of funding and staff affects this Division too, and maintenance of these critical defence works is not yet at the desired standard. However, a new maintenance and rehabilitation programme is in place and so this concern should abate in coming years. The problem of contamination of groundwater, however, is still not being addressed systematically.

An intricate system of water conservancies and drainage and irrigation has been constructed to control flooding and overcome the seasonality of rainfall for coastal agriculture. However, for lack of maintenance, drainage ditches are often silted up or clogged with garbage, the mechanical pumps fail and sluice gates that control the flow of water often do not function properly, leading to frequent fresh water flooding. At high tides the flooding is exacerbated because gravity drainage seaward has to be blocked. The drainage and irrigation systems have profoundly altered the natural surface water regime, which is likely to have significant environmental repercussions. Nevertheless, no structured monitoring of such effects is conducted, except in the MMA-ADA Project.

Integrated Coastal Zone Management

Even though the coastal zone supports the majority of the population and the main economic activities, there is no formal coastal zone management plan or strategy for the multiple uses to which these resources may be put. Many agencies have shorezone management responsibilities, including the Environment Unit, the Hydraulics Division, the Hydro-Meteorology Department and Fisheries Department, and the Central Planning and Housing

Department. This last agency is responsible for planning and zoning in urban and rural settlements, the implementation of standards and regulations and development control. Government has recognised that improved coastal zone management depends on an integrated approach. In 1991 Government established a subcommittee on coastal zone management, formed by representatives from the major agencies dealing with the coastal zone. The next step should be more complete incorporation of coastal communities into the process of developing plans for the coastal zone and implementing them.

TERRESTRIAL BIOMES

The biome concept organizes large-scale ecological variation. Terrestrial biomes are distinguished primarily by their predominant vegetation, and are mainly determined by temperature and rainfall.

Differences in temperature or precipitation determine the types of plants that grow in a given area. Generally speaking, height, density, and species diversity decreases from warm, wet climates to cool, dry climates. Raunkiaer (1934) classified plant life forms based on traits that varied with climate. One such system was based on the location of the perennating organ. These are tissues that give rise to new growth the following season, and are therefore sensitive to climatic conditions. The relative proportions of different life forms vary with climate. In fact, life form spectra are more alike in similar climates on different continents than they are in different climates on the same continent. Regions of similar climate and dominant plant types are called biomes. This chapter describes some of the major terrestrial biomes in the world; tropical forests, savannas, deserts, temperate grasslands, temperate deciduous forests, Mediterranean scrub, coniferous forests, and tundra.

Tropical Forest Biomes

Tropical forests are found in areas centered on the equator. Central and South America possess half of the world's tropical forests. Climate in these biomes shows little seasonal variation, with high yearly rainfall and relatively constant, warm temperatures. The dominant plants are phanerophytes - trees, lianas, and epiphytes. Tropical rainforests have an emergent layer of tall trees over 40 m tall, an overstory of trees up to 30 m tall, a sub-canopy layer of trees and tall shrubs, and a ground layer of herbaceous vegetation.

Tropical forests have the highest biodiversity and primary productivity of any of the terrestrial biomes. Net primary productivity ranges from 2–3 kg m^{-2} y^{-1} or higher. This high productivity is sustained despite heavily leached, nutrient poor soils, because of the high decomposition rates possible in moist, warm conditions. Litter decomposes rapidly, and rapid nutrient uptake is facilitated by mycorrhizae, which are fungal mutualists associated with plant roots.

The tropical forest biome is estimated to contain over half of the terrestrial species on Earth. Approximately 170,000 of the 250,000 described species of vascular plants occur in tropical biomes. As many as 1,209 butterfly species have been documented in 55 square kilometers of the Tambopata Reserve in southeastern Peru, compared to 380 butterfly species in Europe and North Africa combined.

The tropical forest biome is composed of several different sub-biomes, including evergreen rainforest, seasonal deciduous forest, tropical cloud forest, and mangrove forest. These sub-biomes develop due to changes in seasonal patterns of rainfall, elevation and/or substrate.

Savanna Biomes

Located north and south of tropical forest biomes are savannas, with lower yearly rainfall and longer dry seasons. These biomes are dominated by a mix of grasses and small trees. Savannas cover 60% of Africa and represent a transition from tropical forests to deserts. Trees in savannas are usually drought deciduous. Several savanna types associated with differing rainfall patterns, height of the water table and soil depth can be distinguished by their relative abundance of trees and grass.

Repetitive dry season fires have occurred in the African savanna over the last 50,000 years. Fire plays a major role in the balance between trees and grasses in savannas. With long periods between fires, tree and shrub populations increase. Fires release nutrients tied up in dead plant litter. Soil provides a good thermal insulator, so seeds and below ground rhizomes of grasses are usually protected from damage.

Net primary productivity ranges from 400–600 g m^{-2} yr^{-1}, but varies depending upon local conditions such as soil depth. Decomposition is rapid and year-round, and the annual turnover rate of leaf material is high; up to 60–80%. This turnover is aided by the rich diversity of large herbivores found in savannas, where up to 60% of the biomass can be consumed in a given year. Dung beetles are important components of the nutrient cycle due to their role in breaking down animal droppings. The high herbivore diversity and production is mirrored by the great variety of predators and scavengers found in savannas.

Desert Biomes

Deserts generally occur in a band around the world between 15–30° N and S latitude. They cover between 26–35% of the land surface of the Earth. The climate of deserts is dominated by low precipitation, generally below 250 mm yr^{-1} . However, there is a lot of variability in desert types, with hot deserts, cold deserts, high elevation deserts, and rain shadow deserts. Consequently, there is a great deal of variation in the biodiversity, productivity and organisms found in different types of desert.

The dominant plant biomass in most deserts is composed of perennial shrubs with extensive roots and small, gray or white leaves. However, in warm deserts, therophytes (annual plants) can make up most of the species diversity. Desert annuals can survive unpredictable dry periods as seeds. Seeds may remain viable in the soil for several years, until the appropriate rainfall and temperature conditions occur, after which they will germinate. These annuals grow rapidly, completing their life cycle in a few weeks, then flowering and setting seed before soil water reserves are depleted. Winter desert annuals in North American deserts can generate over 1 kg m^{-2} of biomass in a wet year.

With the exception of large blooms of annuals, net primary productivity in most deserts is low and extremely variable. There is a positive relationship between productivity and precipitation, and values can range from near 0 to 120 g m^{-2} yr^{-1}. Just as with savannas, productivity will vary with soil depth and local drainage patterns (e.g., washes).

Grassland Biomes

Grassland biomes occur primarily in the interiors of continents and are characterized by large seasonal temperature variations, with hot summers and cold winters. Precipitation varies, with a strong summer peak. The type of grassland community that develops, and the productivity of grasslands, depends strongly upon precipitation. Higher precipitation leads to tall grass prairie with a high biodiversity of grasses and forbs. Lower precipitation leads to short grass prairies and arid grasslands.

Net primary productivity in dry grasslands may be 400 g m^{-2} yr^{-1}, while higher precipitation may support up to 1 kg m^{-2} yr^{-1}. Grasslands grade into deciduous forest biomes on their wetter margins, and deserts on their drier margins. The borders between grasslands and other biomes are dynamic and shift according to precipitation, disturbance, fire and drought. Fire and drought will favor grassland over forest communities.

Three major selective forces dominate the evolution of plant traits in grasslands, recurring fire, periodic drought, and grazing. These factors have led to the dominance of hemicryptophytes in grasslands with perennating organs located at or below the soil surface. Many grasses have below ground rhizomes connecting above ground shoots or tillers. Grass blades grow from the bottom up, with actively dividing meristems at the base of the leaf. Thus when grazers eat the grass blade, the meristem continues to divide and the blade can continue to grow. Grasses are often decay-resistant, and recurring cool, fast moving surface fires started by lightning at the end of summer aid in nutrient recycling. Fires stimulate productivity and the germination of fire resistant seeds. Many of the world's largest terrestrial animals are found in grasslands. Animals such as gray kangaroos (*Macropus giganteus*) in Australia, Bison (*Bison bonasus*) and horses (*Equus* spp.) in Eurasia and North America were part of species rich assemblages of grazing animals, their predators, and scavengers. Remnant herds in North America suggest that disturbances due to grazers increased local biodiversity by creating openings that rare species could colonize. Large grazers also accelerated plant decomposition through their droppings, creating nutrient hotspots that altered species composition.

Temperate Deciduous Forest Biome

Temperature deciduous forests occur in mid-latitudes where cool winters, warm summers, and high year round precipitation occurs. Net primary productivity ranges from 600–1500 g m^{-2} yr^{-1} with high litter production. Litter serves as a major pathway for nutrient recycling. This biome is named for the dominant trees that drop their leaves during the winter months. These forests may have an overstory of 20–30 m tall trees, an understory of 5–10 m trees and shrubs, a shrub layer around 1–2 m in height, and a ground layer of herbaceous plants. Biodiversity is relatively high in this biome due to the niche partitioning allowed by the multiple forest layers. More complex forests are associated with a greater number of animal species; for example, bird species diversity shows a positive correlation with forest height and number of layers.

MEDITERRANEAN CLIMATE BIOMES

This small biome (about 1.8 million square km) is separated into five separate regions between 30–40 degrees N and S latitude with hot, dry summers, and cool, moist winters. Unrelated evergreen, sclerophyllous shrubs and trees have evolved independently in each of these areas, representing a striking example of convergent evolution. Net primary productivity varies from 300–600 g m^{-2} yr^{-1}, dependent upon water availability, soil depth, and age of the stand. Stand productivity decreases after 10–20 years as litter and woody biomass accumulates. Recurring fires aid in nutrient cycling and many plants show fire-induced or fire-promoted flowering. Some species are able to resprout from buds protected by the soil, while others germinate from decay-resistant seeds that lie dormant in the soil until a fire promotes their germination. Therophytes make up a large component of the flora, and their appearance is associated with openings created by fires.

Northern Coniferous Forest Biome

Located at higher latitudes is a biome dominated by needle-leaved, drought tolerant, evergreen trees, and a climate consisting of long, cold winters and short, cool summers. Biodiversity is low in this two-layered forest made up of an overstory of trees and a ground layer of herbs or mosses. The overstory in much of the boreal forest is made up of only one or two species. The low biodiversity is mirrored by low net primary productivity of 200–600 g m^{-2} yr^{-1}. Productivity varies with precipitation, the length of the frost-free period, and local soil drainage. In flooded areas, sphagnum bogs may develop. The acidic tissue of sphagnum, and the anoxic, flooded conditions, slows decomposition, resulting in the production of peat bogs.

Biomass in tree trunks and long-lived evergreen leaves results in nutrients being stored in the plants. Low temperatures lead to slow decomposition and high litter accumulation. Up to 60% of the biomass may be tied up in litter and humus. Soils are heavily leached, and permafrost underlies much of the soil. Consequently, trees have shallow root systems and rely on extensive mycorrhizal associations for nutrient uptake.

Tundra Biome

At latitudes beyond the boreal forest tree line lies a marshy area where growing seasons are very short and temperatures are below zero degrees Celsius for much of the year. Because of these low temperatures and short growing seasons, net primary productivity is very low in the tundra, between 100–200 g m^{-2} yr^{-}

[1]. Productivity varies with snowfall depth and local drainage. Rocky fields and dry meadows will have lower productivity than moist, low-lying areas and wet meadows.

Biodiversity in the tundra is low and dominated by mosses, lichens, and low-growing perennial shrubs. The tundra biome contains only about 3% of the world's flora. Up to 60% of the flora can be made up of long-lived hemicryptophytes. Windy conditions and low temperatures select for low growing shrubs, often with tightly-packed, rounded canopies with closely spaced leaves and branches. Wind and ice damage help form this shape by pruning branches. The canopy morphology reduces wind speeds and absorbs solar radiation, resulting in canopy temperatures on sunny days more than 10° C above air temperature.

Soils are low in nutrients due to slow decomposition rates and plants retain nutrients in long-lived evergreen tissues. Nitrogen fixation by lichens with cyanobacterial components is a major source of soil nitrogen. Animals have extended hibernation periods or migrate seasonally.

TYPES OF BIOGEOGRAPHY

Today, biogeography is broken into three main fields of study. The three fields are historical biogeography, ecological biogeography, and conservation biogeography. Each field, however, looks at phytogeography and zoogeography.

Historical biogeography is called paleobiogeography and studies the past distributions of species. It looks at their evolutionary history and things like past climate change to determine why a certain species may have developed in a particular area. For example, the historical approach would say there are more species in the tropics than at high latitudes because the tropics experienced less severe climate change during glacial periods. This led to fewer extinctions and more stable populations over time. The branch of historical biogeography is called paleobiogeography because it often includes paleogeographic ideas-most notably plate tectonics. This type of research uses fossils to show the movement of species across space via moving continental plates. Paleobiogeography also takes varying climate as a result of the physical land being in different places into account for the presence of different plants and animals.

Ecological biogeography looks at the current factors responsible for the distribution of plants and animals. The most common fields of research within ecological biogeography are climatic equability, primary productivity, and habitat heterogeneity.

Climatic equability looks at the variation between daily and annual temperatures. It is harder to survive in areas with high variation between day and night and seasonal temperatures. Because of this, there are fewer species at high latitudes because more adaptations are needed to be able to survive there. In contrast, the tropics have a steadier climate with fewer variations in temperature.

This means plants do not need to spend their energy on being dormant and then regenerating their leaves and/or flowers, they don't need a flowering season, and they do not need to adapt to extreme hot or cold conditions. Primary productivity looks at the evapotranspiration rates of plants. Where evapotranspiration is high, so is plant growth. Therefore, areas like the tropics that are warm and moist foster plant transpiration allowing more plants to grow there. In high latitudes, it is simply too cold for the atmosphere to hold enough water vapour to produce high rates of evapotranspiration and there are fewer plants present.

Finally, habitat heterogeneity leads to the presence of more biodiversity. After looking at the various fields in historic and ecological biogeography, conservation biogeography developed. This is the protection and/or restoration of nature and its flora and fauna.

Biogeography is important as a branch of geography that sheds light on the natural habitats around the world. It is also essential in understanding why species are in their present locations and in developing protecting the world's natural habitats.

GEOGRAPHICAL DISTRIBUTION OF ECOSYSTEMS

The global distribution of plant communities generally tracks global latitudinal climate zones and the elevation-dependent patterns of temperature and precipitation in alpine topography. Five broadly defined vegetation zones — semi-arid grasslands, temperate forests, tropical forests, arid deserts, and polar regions — characterize the global distribution of plant communities. Each zone has distinctive ground surface coverage, reinforcement, soil types, and weathering properties that result from its plant communities. Plants in grassland and forest zones not only generate different types of soils, but their root systems reinforce soils differently so the landscapes differ in their resilience to environmental disturbance as well. Grasslands generally have more biomass below ground than above ground, most of it in roots.

Grasslands are particularly vulnerable to erosion following overgrazing and plowing. Temperate forests can be deciduous or coniferous. In temperate forests, extensive root networks form interlocking webs that mirror the extent of the forest canopy and significantly reinforce hillside soils. Geomorphically important effects of forest type include the depth and strength of root penetration, and the shape of fallen trees that enter rivers where the difference between a long pole shape typical of conifers and the branching structure typical of deciduous trees influences the stability and transportability of wood. Tropical forests typically have little below ground organic matter and extensively weathered soils. As plant nutrients are held in the plants themselves, it can be hard to re-establish native forests after forest clearing. In contrast to temperate and tropical regions where vegetation can have a major impact on the type, frequency, and intensity of geomorphological processes, vegetation plays a relatively minor geomorphological role in arid and polar landscapes. However, even in desert landscapes where plant communities have little biomass or plant cover, the presence or absence of even a little ground cover or a thin web of roots can greatly affect soil development. And frozen soils that support small trees and tundra vegetation can accumulate and store lots of soil carbon due to slow breakdown. The potential for warming tundra soils to release carbon into the atmosphere is one of the great concerns surrounding potential feedbacks between climate change and ecosystem response.

The distribution of animal communities also generally tracks climate zones. Penguins don't live in deserts, and camels don’t live on glaciers. Although most animals only marginally influence the landscapes they inhabit, a few types of animals have a substantial geomorphological influence. For example, mass spawning salmon move up to half the gravel transported by some rivers in the Pacific Northwest. Overgrazing by domestic animals accelerates soil erosion and can trigger gully development. Burrowing animals and mound building ants and termites can displace and mix tremendous amounts of soil and weathered rock. Charles Darwin calculated that over the course of centuries worms steadily plowed the hillside soils of England. Plants and animals influence geomorphological processes directly, as when burrowing activity and roots mechanically pry rocks, and indirectly, as when plants protect soils from erosion during precipitation events, and roots mechanically reinforce slope-forming materials. Plants also are central to the chemical transformations that accompany the breakdown of rock-forming minerals into clay minerals that hold nutrients essential to soil fertility. Plant communities thus shape how a landscape weathers, erodes, and supports life. The size of an organism is not necessarily related to its importance or impact. Soil bacteria, for example, are essential chemical weathering agents in many environments.

Humans

Humans are today the most widely distributed species on the planet, and we move enough rock and soil to count among the primary geomorphic forces shaping Earth's modern surface. Coal and mineral mining operations move whole mountains and excavate great pits, farmers’ plows push soil gradually but persistently downhill, and construction crews cut or fill the land to facilitate building or to suit our aesthetic whims. Human activities further influence geomorphological processes through the indirect effects of our resource management and land use practices. In manipulating our world, we alter hydrological processes by changing surface run-off, stream flow, and flood flows. Clearing stabilizing vegetation and changing water fluxes in the landscape affects slope stability, and increases erosion rates, and construction of dams and coastal jetties interupts the transport and storage of sediment. Such changes often have unintended consequences far downstream, as when upriver dam construction starves beaches and deltas of sand and mud by trapping the sediment that formerly nourished coastal environments. Learning to recognize and understand such connections is central to applied geomorphology, whether to aid in the design resilient communities, develop more sustainable land use practices, or construct measures to protect critical infrastructure. Through history human activities have resulted in changes to a wide range of local and landscape-scale geomorphological processes that we are still learning to recognize and fully appreciate. For example, we are just coming to understand the profound impact of Bronze Age forest clearing on European rivers. Further dramatic changes in regional and global land cover are projected in the coming century. The influence of human activity is already great enough on a global scale that geologists have proposed we are entering a new era of geologic time that they call the Anthropocene (the human era). Over the next century, changes in the global climate are predicted to cause increasingly variable weather, more frequent hurricanes, rising sea levels, and a host of related regional impacts, like the loss of winter snow pack in the Pacific Northwest. Predicting the ways that landscapes respond to such changes will be central to planning societal adaptation or mitigation efforts.

Landscapes

Landscapes are suites of contiguous landforms that share a common genesis, location, and history. The study of landscapes involves investigations over a tremendous range of spatial and temporal scales, from the mobilisation of a single grain of sand from a river bed over a few seconds, to the rise of the Himalaya and growth of the Tibetan Plateau over millions of years. Consequently, the approach, methods, and scale of analysis involved in any particular study need to be tailored to the questions the geomorphologist seeks to address. Landscapes can be divided into distinct units that can be studied over discrete periods of time, but it is the relationships between processes and landforms that are truly fundamental in our modern approach to geomorphology. In seeking to understand landscape evolution it is important to appropriately match measurement and understanding of geomorphological processes to the spatial and temporal scales over which relevant processes act.

Process and Form

Landscape forms and surface processes are inseparably linked. Stream flow, slope failure, flowing glaciers, and blowing wind act to shape landscapes. At the same time, topography itself determines the style and rate of geomorphological processes. The shapes and orientations of larger-scale landforms generally control the rates and distributions of the small-scale erosional and depositional processes that determine how landforms evolve over time. The fundamental interdependence of process and response means that a geomorphologist can often read form to infer process, as in determining dominant wind directions from the shape and orientation of sand dunes. But in order to understand landforms and predict landscape response, we must understand the processes that form them. Consequently, the relationship between process and form lies at the heart of geomorphology.

The geological and environmental history of a region can leave a lasting signature on landforms and on the processes operating upon them. The physiographic signature of long-vanished glaciers still dominates the topography of alpine regions around the world. It should not be surprising then that process geomorphology and historical geomorphology are complementary disciplines. Although many geomorphologists specialize in one or the other approach, no geomorphologist can afford to ignore either.

Proposing testable hypotheses and interpreting field, laboratory, and simulation data in the evaluation of those hypotheses requires consideration of processes over time because of the fundamental linkages between landscape history, process, and form.

Landscape dynamics and evolution result from the interaction of multiple systems that can be studied and understood in their own right. The topography of a mountain belt reflects the interaction of tectonic processes that raise rocks above sea level with the hydrologic and run-off processes that govern how erosion acts to shape slopes and incise valleys. Considered broadly, the interaction of coupled tectonic, climatic, and erosional systems control patterns of uplift, erosion, and sedimentation as they change over geologic time. At finer scales, many geomorphological processes reflect the interaction of ecological and hydrological systems, as when the binding effect of tree roots helps to stabilize soils on landslide-prone slopes, or when log jams create dams that divert stream channels to new courses across their floodplains. Understanding landscapes often requires an a ppreciation of how systems interact in different regional contexts and environmental settings.

Spatial Scales

At global and continental scales, geomorphologists study major physiographic features like mountain belts, depositional basins, and great river systems like the Mississippi, Amazon, or Nile. At these scales, broad patterns in global climate and plate tectonics influence patterns of erosion and deposition that, in turn, influence the size and extent of mountains, plateaus, lowlands, coastal plains, and river basins. Such patterns also affect the distribution of soil types and the relative importance of glacial, fluvial, eolian (wind-driven), and coastal processes in shaping topography.

At a regional scale, distinct physiographic provinces reflect areas with broadly similar history, landforms, and landscape dynamics. Examples of such provinces include mountain belts like the Sierra Nevada or Appalachians as well as features like the Great Plains, California's Central Valley, and the Colorado Plateau in the American Southwest. Physiographic provinces are areas in which similar suites of geomorphological processes govern landscape formation and dynamics, and thus where one finds similar suites of landforms. A drainage basin is the land surface area drained by a given stream. Small streams come together to form larger rivers, so landscapes are naturally organized into smaller drainage basins nested within larger drainage basins.

Drainage basins range in size from a headwater catchment that collects water from a single mountain hillside to the Amazon River basin that drains more than half of South America. Drainage divides are topographic ridges that separate drainage basins.

Because streamflow is the predominant agent of erosion and sediment transport on land, drainage basins are the logical unit for analysis of many geomorphological processes. At the scale of individual valley segments, the tectonic or climatic setting of a region often defines areas where different types of processes and/or histories have led to development of distinct landforms and dynamics. The difference between U-shaped valleys carved by glaciers valleys and V-shaped valleys cut by streams is a classic example. Systematic downstream changes in stream valley morphology, from erosional headwater streams with narrow valleys that are confined between bedrock walls, to broad unconfined valleys of depositional lowlands. Distinct suites of valley segment types are diagnostic of specific physiographic provinces, and their character and distribution both vary regionally and generally reflect the history and processes of landscape evolution and shape ecosystem dynamics.

At finer spatial scales, landscapes can be divided into distinct hillslopes, hollows, channels, floodplains, and estuaries. Hillslopes (including hilltops) are the undissected uplands between valleys. Hollows are unchanneled valleys that typically occur at the head of channels in soil-mantled terrain. Channels are zones of concentrated flow and sediment transport within well-defined banks, and floodplains are the flat valley bottoms along river valleys that are inundated during times of high discharge under the present climate. Estuaries are locations where streams enter coastal waters to arrive at their ultimate destination — sea level.

Temporal Scales

The scale of observations in both time and space strongly influence geomorphic interpretations. Matching the scale of observation to the scale of the question you seek to answer is critical for gathering meaningful data. It's easy to understand the importance of spatial scale. Measuring erosion on a single hillside in Kenya won't tell you much about the erosion rate of the African continent. It is more difficult to understand the influence of time on geomorphic data, observations, and interpretations.

Consider how the first estimates of continental erosion rates, which were made by measuring the concentration of suspended sediment exported by rivers over a few years, turned out to be wrong. While this is a reasonable approach if the measurements capture the variability of the system over time, in this case they did not. With only a few years of data, sediment yield results are likely to be biased by the short period of observation because most streams systems experience rare but massive floods that periodically transport immense amounts of sediment. How would one know that the few years in which the sampling occurred are representative of a meaningful, long-term average? The issue of how to integrate the influence of large and small events in shaping larger landforms remains central to modern process geomorphology.

Topography evolves over periods of time that range from the millions of years that are required to erode away mountain belts, to the few seconds, minutes, or days it takes for a landslide, flood, or earthquake-driven fault displacement to disrupt the land surface. Climate cycles influence topography over millennia as glaciers advance, retreat, and scour out alpine valleys. Likewise, river profiles adjust to the sea level changes that accompany glaciations. Landscape responses to large-scale disturbances like hurricanes and volcanic eruptions are often evident for centuries, and it can take decades for landslide scars to revegetate and river channels to process the sediment shed from slopes during large storms. River flow exhibits annual and seasonal variability that controls the timing of sediment movement and structure of stream ecosystems. Because of the disproportionate influence of infrequent extreme events like storms, landslides, and floods, rates of processes measured over short time spans may not adequately characterize average rates over longer time scales. Not surprisingly, geomorphologists deal with a wide variety of measurements over different time scales, from rates directly measured in the field, to indirect measurements of long term erosion rates inferred from isotopic analyses, and erosion rates constrained by sedimentary volumes preserved in depositional basins. The key, of course, is to employ analyses relevant to the time scale of interest.

3

Global Distribution of Plants, Animals and Forests

PLANT LIFE FORMS

Phanerophytes

Phanerophytes (from the Greek *phaneros,* meaning visible) are trees and large shrubs. They bear their buds on shoots that project into the air and are destined to last many years. The buds are exposed to the extremes of climate. The primary shoots, and in many cases the lateral shoots as well, are negatively geotropic (they stick up into the air). Weeping trees are an exception. Raunkiaer divided phanerophytes into twelve subtypes according to their bud covering (with bud-covering or without it), habit (deciduous or evergreen), and size (mega, meso, micro, and nano); and three other subtypes herbaceous phanerophytes, epiphytes, and stem succulents. A herbaceous example is the scaevola, *Scaevola koenigii.* Phanerophytes are divided into four size classes: megaphanerophytes (> 30 m), mesophanerophytes (8-30 m), microphanerophytes (2-8 m) and nanophanerophytes (< 2 m).

Chomaephytes

Chamaephytes (from the Greek *khamai,* meaning on the ground) are small shrubs, creeping woody plants, and herbs. They bud from shoot-apices very close to the ground. The flowering shoots project freely into the air but live only during the favourable season. The persistent shoots bearing buds lie along the soil, rising no more than 20-30 cm above it. Suffructicose chamaephytes have erect aerial shoots that die back to the ground when the unfavourable season starts. They include species of the Labiatae, Caryophyllaceae, and Leguminosae. Passive chamaephytes have procumbent persistent shoots—they are long, slender, comparatively flaccid, and heavy and so lie along the ground. Examples are the greater stitchwort *(Stellaria holostea)* and the prostrate speedwell (*Veronica prostrata)*. Active chamaephytes have procumbent persistent shoots that lie along the ground because they are transversely geotropic in light (take up a horizontal position in response to gravity). Examples are the heath speedwell *(Veronica officinalis),* the crowberry *(Empetrum nigrum),* and the twinflower *(Linnaea borealis)*. Cushion plants are transitional to hemicryptophytes. They have very low shoots, very closely packed together. Examples are the hairy rock-cress *(Arabis hirusa)* and the houseleek *(Sempervivum tectorum)*.

Hemicryptophytes

Hemicryptophytes (from the Greek *kryptos,* meaning hidden) are herbs growing rosettes or tussocks. They bud from shoot-apices located in the soil surface. They include protohemicryptophytes (from the base upwards, the aerial shoots have elongated internodes and bear foliage leaves) such as the vervain *(Verbena officinalis),* partial rosette plants such as the bugle *(Ajuga reptans),* and rosette plants such as the daisy *(Bellis perennis)*.

Cryptophytes

Cryptophytes are tuberous and bulbous herbs. They are even more 'hidden' than hemicryptophytes—their buds are completely buried beneath the soil, thus affording them extra protection from freezing and drying. They include geophytes (with rhizomes, bulbs, stem tubers, and root tuber varieties) such as the purple crocus *(Crocus vernus),* helophytes or marsh plants such as the arrowhead *(Sagittaria sagittifolia),* and hydrophytes or water plants such as the rooted shining pondweed *(Potamogeton lucens)* and the free-swimming frogbit *(Hydrocharis morsus-ranae)*.

Therophytes

Therophytes (from the Greek *theros,* meaning summer) or annuals are plants of the summer or favourable season and survive the adverse season as seeds. Examples are the cleavers *(Galium aparine),* the cornflower *(Centaurea cyanus),* and the wall hawk's-beard *(Crepis tectorum)*.

An example of the 'autoecological accounts' for the bluebell *(Hyacinthoides non-scripta*. The bluebell is a polycarpic perennial, rosette-forming geophyte, with a deeply buried bulb. It appears above ground in the spring, when it exploits the light phase before the development of a full summer canopy. It is restricted to sites where the light intensity does not fall below 10 per cent of the daylight between April and mid-June, in which period the flowers are produced. Shoots expand during the late winter and early spring. The seeds are gradually shed, mainly in July and August. The leaves are normally dead by July. There is then a period of aestivation (dormancy during the dry season). This ends in the autumn when a new set of roots forms. The plant cannot replace damaged leaves and is very vulnerable to grazing, cutting, or trampling. Its foliage contains toxic glycosides and, though sheep and cattle will eat it, rabbits will not. Its reproductive strategy is intermediate between a stress-tolerant ruderal and a competitor—stress-tolerator—ruderal 103). It extends to 340 m around Sheffield, but is known to grow up to 660 m in the British Isles. It is largely absent from skeletal habitats and steep slopes. The bluebell commonly occurs in woodland. In the Sheffield survey, it was recorded most frequently in broad-leaved plantations. It was also common in scrub and woodland overlying either acidic or limestone beds, but less frequent in coniferous plantations. It occurs in upland areas on waste ground and heaths, and occasionally in unproductive pastures, on spoil heaps, and on cliffs. In woodland habitats, it grows more frequently and is significantly more abundant on south-facing slopes. However, in unshaded habitats, it prefers north-facing slopes. It is not found in wetlands. It can grow on a wide range of soils, but it most frequent and more abundant in the pH range 3.5-7.5. It is most frequent and abundant in habitats with much tree litter and little exposed soil, though it is widely distributed across all bare-soil classes.

DISTRIBUTION OF SPECIES

Why are palm trees found in Florida, Egypt, and India? Why are there so many species of plants and animals in the Amazon rainforest, but so few in Siberia? Why are some animals only found in Australia, while others can be found on every continent except Antarctica?

The distribution of plant and animal species is a key topic in biogeography, the study of the relationship between geography and living things. While every species is unique, all are in some way impacted by the landforms, resources, and climates they're exposed to. So, if you want to understand species distribution, geography is a good place to start!

Latitude & Climate

If you drew lines horizontally across the world, you might notice something interesting: many of the world's largest rainforests would fall along the same line, and many of the world's largest deserts would fall on a different line. Why is this?

Latitude is the degree of distance from a place to the equator, which is an imaginary line representing the central point of the planet. So, why are we talking about this? Places on the same latitudinal line get roughly the same access to sunlight throughout the year, so they tend to have very similar climates. As a result, they tend to have similar kinds of species.

Let's imagine that we begin on the equator and head north. For about 15 degrees of latitude, we're going to be in a climate with lots of rain and consistent year-round temperatures. As a result, tropical rainforests grow here, leading to a huge diversity in plant life. With all the plant resources and the warm weather, countless species of fungi, insects, reptiles, amphibians, birds, and mammals can be found here as well.

If we move further from the equator, however, things start to change. First, climates get a bit drier, with more pronounced seasons. Next, we see huge deserts with very little rain, and above those are semi-arid grasslands. If we go even further, we'll encounter temperate forests with deciduous trees. If we go beyond this, we'll encounter subarctic conditions, which are much colder, before finally entering the Arctic Circle. While there are exceptions, this is the general trend all over the world. Latitude seems to have a big impact on species diversity and distribution. Answer this question: do you expect to find more plant and animal species in the tropical rainforests of Central America or the grasslands of the Great Plains? How about the arctic tundra? Biologists have long observed that there tend to be more species in regions near the equator than further from it. We call this concept the latitudinal diversity gradient, which basically just means that diversity of species declines as you move further from the equator and closer towards either the North or South Pole.

DISTRIBUTION OF PLANTS

There is a wide range of variations in the distri-bution of vegetation on the globe. There is a zonal pattern of vegetation from equator towards the poles and from seal level to vegetation level on the high mountains.

The distribution of plants is affected and controlled by a variety of factors e.g.:

(i) Climatic factors (sunlight, temperature, moisture and humidity, pre-cipitation, soil-moisture etc.);

(ii) Edaphic factors (soil nutrients, soil texture, soil structure, acidity and alka-linity, nature and properties of soil profiles etc.);

(iii) Biotic factors (effects of living organisms mainly animals and man of a particular habitat on plants, interactions between different plant species and between plants and animals like natural selection, com-petition, mutualism, paraticism etc.);

(iv) Physical fac-tors (reliefs and topography, slope angle, gradient and slope aspect, etc.);

(v) Tectonic factors (continental displacement and drift, plate movements, endogenetic forces and movements, vulcanicity and seismic events etc.);

(vi) Fire factor (forest fire-natural forest fire through lightning, man-induced forest fire-both inten-tional and accidental;

(vii) Dispersion of plants, and

(viii) Human interferences.

Distribution of plants may be attempted in a variety of ways viz.:

(i) On the basis of habitats as the distribution of terrestrial and aquatic plants,

(ii) On the basis of floral divisions,

(iii) On the basis of latitudinal and altitudinal extents, and

(iv) On the basis of characteris-tic features of plant communities etc.

The land plant species of the world are grouped into 6 major floristic kingdoms on the basis of their worldwide distribution as given below:

Australian Kingdom

This floristic kingdom includes the plants of whole Australia which is characterized by typical plant species e.g., eucalyptus. The different species of this unique genera of eucalyptus are so dominant in Aus-tralia that they represent 75 percent of all Australian plants. There are over 600 species of eucalyptus which greatly vary as regards their general characteristics as they range from tall, giant and shady eucalyptus trees to dwarf and stunted desert eucalyptus trees. Eucalyp-tus is said to be related to mimosa which is still found in South America (only a few species).

Eucalyptus has been dispersed and distributed by man (deliberately) from Australia to almost every continent. One can see extensive plantation of eucalyptus in India particularly along the rail and road sides and it is being expanded rapidly by deliberate actions of man in all parts of the country irrespective of environmental requirements and suitability of this unique exotic plant. The typical endemic floras of Australia having unique characteris-tics have developed due to its isolation from other continents of the southern hemisphere because of con-tinental drift.

Cape Kingdom

The floral kingdom has developed in the south-ern tip of Africa wherein the plants having bulbs and tubers have developed and these represent the typical plant species of this floral kingdom. The plants of this kingdom belong to the category of cryptophytes which bear buds in the form of bulbs and tubers which are buried in the soils. These bulbs and tubers give birth to other plants as new shoots come out from these bulbs and tubers and are developed as plants.

These plants represent most plants of the gradient such as garden flowering plants (e.g., Loplia, Kniphogia, Erica Freesia etc.). The dispersal of these garden plants became possible when South Africa was colonized by Europe-ans who distributed these garden flowering plants from South Africa to the gardens of other parts of the world.

There is gradual decrease in the number and area of these garden flowering plants in their own native areas (southern part of South Africa) because their areas are continuously being replaced by agricultural lands. The untouched areas still have sclerophyllous shrubs which attain the height of a few meters. There is undergrowth of herbaceous shrubs in the sclerophyllous shrubs.

It may be remembered that the native vegetation of this region before the European colonization consisted of temperate evergreen forests which were extensively cleared off by the Europeans for agricultural proposes and thus the sclerophyllous shrubs developed in this region at later date as secondary succession of vegeta-tion.

Antarctic Kingdom

This kingdom includes a narrow strip in the north of Antarctica which runs from Patagonia and southern Chile of South America to New Zealand. The most important representative plant of this zone is Nothofagus which is also known as Southern Beech. About 100 million years ago temperate grasses devel-oped as the native vegetation of this region (New Zealand).

The most outstanding and typical species of the grasses were Tussock Grasses though a few spe-cies of Sedges (plants which grow in water) and dicoty-ledon shrubs were also developed but these original native vegetation have undergone massive modification and transformation since the colonization of New Zealand by the Europeans.

Thus, the present-day veg-etation of New Zealand is of modified type which is still characterized by two types of tussock grasses viz.:

(i) Short Tussock Grasslands have two main species e.g., festuca and poa. The average height of these grass is upto 0.5 m and the colour is yellow-grey,

(ii) Tall Tussock Grasslands have the main species of Chiomechloa.

Warm temperate areas of New Zealand are characterized by the dominance of the forest of gym-nosperms and angiosperms trees. The main species of the coniferous family of gymnosperms are Podcarpaceae, Cupressaceae and Araucariaceae whereas flowering plants are included in Angiosperms of which Nothofagus is the most important plant.

The sub-tropical forests of New Zealand are of evergreen type which is characterized by dense cover of tall trees having different vertical strata of other plants. The original vegetation of New Zealand has been greatly modified and destroyed by human activities and the mammals (mainly grazing red deers and rabbits) brought by them from Europe. This has led to the destabilization of vegetation community at large scale.

Palaeotropical Kingdom

This kingdom includes most of Africa, South West Asia, South Asia, South East Asia and southern and middle portions of China.

This floral kingdom is further divided into 3 sub-kingdoms e.g.:

(i) African sub-kingdom,

(ii) Indo-Malaysian sub-kingdom, and

(iii) Polynesian sub-kingdom.

This floral kingdom is also divided into several floral provinces or regions e.g., West African rainforest region, Mada-gascar region, Iran-Turanian region, East Asian re-gion, etc. There is great variation in plant species from one region to another region but few plants are common to all sub- kingdoms and regions.

Neotropical Kingdom

This region includes the whole of South America except southern Chile and Patagonia. A few genera are common to this kingdom and palaeotropical kingdom mainly Africa because the original flowering plants were developed in South America and Africa during Cretaceous period when all members of Gondwanaland were united together.

Later on the spreading of Atlan-tic sea-floor, disruption of Gondwanaland and west-ward drift of South America from Africa became responsible for the origin and development of new species at regional level and therefore variations in the plant species of South America and Africa were intro-duced.

Boreal Kingdom

This floral kingdom includes the whole of North America except Middle America, Greenland, entire Europe, northern Asia and Arctic region. This is the most extensive kingdom of all the floral kingdoms. This is again divided into several sub-kingdoms and regions or provinces e.g. Rocky Mountainous Region (RMR); Atlantic – North American Region; Arctic and Sub-Arctic Region (ASAR); Europe-Siberian Region (ESR); Mediterranean Re-gion (MR) etc.

Genera and family of plants and major vegetation of the aforesaid floral kingdoms and floral provinces or regions.

POLYPLOIDY AND PLANT GEOGRAPHY

Polyploids are organisms having an increase in the number of chromosome sets above the normal diploid. It is reasonably certain that in any naturally occurring plant series the plants with the lowest chromosome numbers are more primitive than polyploids presumably derived from them. Hagerup, observed a correlation between polyploidy and extreme climates, "those with the higher chromosome numbers are always the ones growing farther north, and thus more exposed to extremes of temperature."

Later correlations were found between increases in percentage of polyploidy and other environmental extremes. The subject has grown considerably and useful summary accounts will be found in Stebbins, Cain, and A. and D. Love. Reese shows that, on available data, polyploidy increases with latitude from North Africa through Europe to the Arctic. He considers that the main correlation is with the age of the flora: the younger the flora the higher the percentage of polyploids.

Those readers particularly interested in the British flora might consult Haskell. Most authors who have written on the ranges and distributions of polyploids conclude that polyploidy confers benefits which enable the species (or other taxon) to extend into less favourable habitats. This is certainly sometimes true but how far wide conclusions are valid is more doubtful. The results as presented are frequently statistical and are sometimes open to criticisms: only parts of floras are included, the chromosome numbers used are based on few reliable counts of wild plants of known origin per species, most of the research has been done in Europe in areas heavily glaciated in the Ice Age, tropical and subtropical floras have been very little examined cytogenetically, and so on. Further, even if it were accepted that polyploidy is, at least on the whole, advantageous in the struggle for existence, there is little or no agreement as to the underlying causes, that is of the nature of the advantages. Structural, physiological, and genetical advantages of various kinds have all been suggested by different authors.

Stebbins said "Perhaps the safest generalization that can be made about polyploids is that they are most numerous in regions that have only recently been open to colonization by plants or that have undergone great changes in their floras in recent times."However, it must also be said that some authors have failed to find such correlations between polyploidy and ranges as indicate that polyploids can withstand less favourable ecological conditions than diploids. Soo and Heiser and Whitaker are examples and the latter even go so far as to say that generalizations involving polyploidy are probably meaningless. While this last is too sweeping a statement there is no doubt that much more research is needed before the full significance of polyploidy for plant geography is known.

THE DISTRIBUTION OF ANIMALS

Scientists are convinced that life came from the sea and from there the living organisms conquered, through the necessary evolutionary stages, both the Earth and the internal freshwaters. These steps, moving from the sea to the other environments, occurred in very ancient times, when the living forms were poorly developed and poorly specialised. Later on, the living beings, even though spreading all around, found impassable boundaries that confined them to certain regions. These boundaries were mountain ridges, deserts, seas, rivers, temperatures, available water, the presence of oxygen in the water, geological events (continental drift, rising of the sea). Animals can be divided on the basis of an ecological criterion (i.e. in relation to the environments in which they live) into marine, freshwater and terrestrial organisms. In between the first two there should be the organisms that live in brackish waters, waters of passage between salty waters and freshwaters. A separate category of terrestrial animals are those that live in tunnels, caves and in the cracks of the ground, animals that altogether compose the "hypogean fauna".

FORESTS OF THE WORLD

The world's forests cover some 3 400 million hectares - an area the size of North and South America combined. They are sources of raw materials and food, and are essential for maintaining agricultural productivity and the environmental well-being of the planet as a whole.

Trees and forests anchor the soil and buffer the winds, thus protecting against erosion by wind and water. They produce oxygen and absorb carbon dioxide, the major agent in global warming. They intercept rainfall, releasing it slowly into soils, surface waters and underground aquifers. The water vapour released from their foliage in transpiration influences climate and is a vital part of the hydrological cycle.

Forests and woodlands vary from the dense rainforests of the tropics to East Africa's open woodland savannahs; from mangroves to the mixed temperate broadleaved and boreal forests. But unmanaged harvesting, ill-planned clearance for farming, or physiological pressures from pollution can pose a threat to any forest type.

During the 1980s more than 15 million hectares of tropical forests were lost each year: the overwhelming majority of the deforestation was intended to provide land for agriculture. The largest losses occurred in tropical moist deciduous forests, the areas best suited for settlement and farming. The extent of these forests declined by 61 million hectares - more than 10 percent of their area -while 46 million hectares, or 60 percent, of tropical rainforests were lost. Few of these areas have been replanted.

Tree cover is increasing in many temperate regions, mainly due to the establishment of forest plantations. Europe increased its forest and wooded land by 2 percent over the 1980s and there were small increases in New Zealand and Australia. In the same decade, however, a drop of some 3.5 million hectares occurred in the United States. The area of the former USSR reported an increase between 1978 and 1988. However, there is an urgent need to bring many of the Siberian forests under sustainable management to avoid their degradation. As well as managing some forests for production, diversity should be preserved in others by designating protected areas.

Many forests in industrialized countries have been damaged by airborne pollutants, including acid rain: the International Institute for Applied Systems Analysis (IIASA) has estimated that US$ 60 000 million would have to be spent annually for 25 years to protect Europe's forests from pollution.

ADAPTING TO CIRCUMSTANCES: NICHES AND LIFE-FORMS

Ways of Living

Organisms have evolved to survive in the varied conditions found at the Earth's surface. They have come to occupy nearly all habitats and to have filled multifarious roles within food chains.

Ecological Niche

An organism's ecological niche (or simply niche) is its 'address' and 'profession'. Its address or home is the habitat in which it lives, and is sometimes called the habitat niche. Its profession or occupation is its position in a food chain, and is sometimes called the functional niche. A skylark's *(Alauda arvensis)* address is open moorland (and, recently, arable farmland); its profession is insect-cum-seed-eater. A merlin's *(Falco columbarius)* address is open country, especially moorland; its profession is a bird-eater, with skylark and meadow pipit *(Anthus pratensis)* being its main prey. A grey squirrel's *(Sciurus carolinensis)* habitat niche is a deciduous woodland; its profession is a nut-eater (small herbivore). A grey wolf's *(Canis lupus)* habitat niche is cool temperate coniferous forest, and its profession is large-mammal-eater.

A distinction is drawn between the fundamental niche and the realized niche. The fundamental (or virtual) niche circumscribes where an organism would live under optimal physical conditions and with no competitors or predators. The realized (or actual) niche is always smaller, and defines the 'real-world' niche occupied by an organism constrained by biotic and abiotic limiting factors.

A niche reflects how an individual, species, or population interacts with and exploits its environment. It involves adaptation to environmental conditions. The competitive exclusion principle precludes two species occupying identical niches. However, a group of species, or guild, may exploit the same class of environmental resources in a similar way. In an oak woodland, one guild of birds forages for arthropods from the foliage of oak trees; another catches insects in the air; another eats seeds. The foliage-gleaning guild in a California oak woodland includes members of four families: the plain titmouse (*Parus inornatus,* Paridae), the blue-gray gnatcatcher (*Polioptila caerulea,* Sylviidae), the warbling vireo and Hutton's vireo (*Vireo gilvus* and *Vireo huttoni,* Vireonidae), and the orange-crowned warbler (*Vermivora celata,* Parulidae).

Ecological Equivalents

Although each niche is occupied by only one species, different species may occupy the same or similar niches in different geographical regions. These species are ecological equivalents or vicars. A grassland ecosystem contains a niche for large herbivores living in herds. Bison and the pronghorn antelope occupy this niche in North America; antelopes, gazelles, zebra, and eland in Africa; wild horses and asses in Europe; the pampas deer and guanaco in South America; and kangaroos and wallabies in Australia. As this example shows, quite distinct species may become ecological equivalents through historical and geographical accidents.

Many bird guilds have ecological equivalents on different continents. The nectar-eating (nectivore) guild has representatives in North America, South America, and Africa. In Chile and California the representatives are the hummingbirds (Trochilidae) and the African representatives are the sunbirds (Nectariniidae). One remarkable convergent feature between hummingbirds and sunbirds is the iridescent plumage.

Plant species of very different stock growing in different areas, when subjected to the same environmental pressures, have evolved the same life-form to fill the same ecological niche. The American cactus and the South African euphorbia, both living in arid regions, have adapted by evolving fleshy, succulent stems and by evolving spines instead of leaves to conserve precious moisture.

Life-forms

The structure and physiology of plants and, to a lesser extent, animals are often adapted for life in a particular habitat. These structural and physiological adaptations are reflected in life-form and often connected with particular ecozones. The life-form of an organism is its shape or appearance, its structure, its habits, and its kind of life history. It includes overall form (such as herb, shrub, or tree in the case of plants) and the form of individual features (such as leaves). Importantly, the Plant life-forms.

A widely used classification of plant life-forms, based on the position of the shoot-apices (the tips of branches) where new buds appear, was designed by Christen Raunkiaer in 1903. It distinguishes five main groups: therophytes, cryptophytes, hemicryptophytes, chamaephytes, and phanerophytes.

A biological spectrum is the percentages of the different life-forms in a given region. The 'normal spectrum' is a kind of reference point; it is the percentages of different life-forms in the world flora. Each ecozone possesses a characteristic biological spectrum that differs from the 'normal spectrum'. Tropical forests contain a wide spectrum of life-forms, whereas in extreme climates, with either cold or dry seasons, the spectrum is smaller. As a rule of thumb, very predictable, stable climates, such as humid tropical climates, support a wider variety of plant life-forms than do regions with inconstant climates, such as arid, Mediterranean, and alpine climates. Alpine regions, for instance, lack trees, the dominant life-form being dwarf shrubs (chamaephytes). In the Grampian Mountains, Scotland, 27 per cent of the species are chamaephytes. Some life-forms appear to be constrained by climatic factors. Megaphanerophytes (where the regenerating parts stand over 30 m from the ground) are found only where the mean annual temperature of the warmest month is 10°C or more. Trees are confined to places where the mean summer temperature exceeds 10°C, both altitudinally and latitudinally. This uniform behaviour is somewhat surprising as different taxa are involved in different countries. Intriguingly, dwarf shrubs, whose life cycles are very similar to those of trees, always extend to higher altitudes and latitudes than do trees.

Individual parts of plants also display remarkable adaptations to life in different ecozones. This is very true of leaves. In humid tropical lowlands, forest trees have evergreen leaves with no lobes. In regions of Mediterranean climate, plants have small, sclerophyllous evergreen leaves. In arid regions, stem succulents without leaves, such as cacti, and plants with entire leaf margins have evolved. In cold wet climates, plants commonly possess notched or lobed leaf margins.

Animal Life-forms

Animal life-forms, unlike those of plants, tend to match taxonomic categories rather than ecozones. Most mammals are adapted to basic habitats and may be classified accordingly. They may be adapted for life in water (aquatic or swimming mammals), underground (fossorial or burrowing mammals), on the ground (cursorial or running, and saltatorial or leaping mammals), in trees (arboreal or climbing mammals), and in the air.

Autoecological Accounts

Detailed habitat requirements of individual species require careful and intensive study. A ground-breaking study was the autoecological accounts prepared for plants around Sheffield, England. About 3,000 km^2 were studied in three separate surveys by the Natural Environment Research Council's Unit of Comparative Plant Ecology (formerly the Nature Conservancy Grassland Research Unit). The region comprises two roughly equal portions: an 'upland' region, mainly above 200 m and with mean annual precipitation more than 850 mm, underlain by Carboniferous Limestone, Millstone Grit, and Lower Coal Measures; and a drier, 'lowland' region overlying Magnesian Limestone, Bunter Sandstone, and Keuper Marl.

4

Types and Distribution of Fisheries, Phytogeography and Phylogeography

FISHERIES: TYPES OF FISHERIES AND IT ECONOMICAL IMPORTANCE

Fisheries: Types of Fisheries and it Economical Importance! Fish are aquatic, cold blooded and craniate vertebrates belonging to the super class Pisces under phylum Chordata. Fishery is a kind of industry which is concerned with the catching, processing or selling of fish, shellfish (molluscs, each has a shell in two halves, used for food, e.g., mussels, oysters, etc.) and crustaceans.

Economic Importance of Fish

Fish as food

The fish flesh is an excellent source of protein, has very little fat, carries a good amount of minerals and vitamins A and D and rich in iodine.

Fish for controlling diseases

Diseases like malaria, yellow fever and other dreadful diseases that are spread through mosquitoes can be controlled. Larvivorous fish eat larva of mosquito. The important larvivorous fish are Gambusia, Panchax, Haplochitus, Trichogaster, etc.

Scientific value

Some fish like the lung fish are of zoological importance because of their discontinuous distribution and anatomical features.

Aesthetic value

A large number of fish are cultured in aquarium for their beauty and graceful movements. The important aquarium fish are Macropodus, Trichogaster, Carassinus (gold fish) and Pterophyllum (angel fish).

Fishery Bye-products

(a) Fish oil: It is extracted from the liver of the sharks, sawfishes, skates and rays and has medicinal value. These mainly include cod liver oil and shark liver oil.

(b) Fish Manure: The fish waste after the extraction of oil, is used as fertilizers,

(c) Fish Glue: It is a sticky product, obtained from the skin of the cod and is used as gum.

(d) Isinglass: It is a gelatinous substance, obtained from the air bladder of perches, Indian Salmons and cat fish used in the preparation of special cement and in the clarification of wine and beer,

(e) Shagreen: The skin of sharks and rays, which has pointed and sharp placoid scales are used in polishing the wood and other materials. It is also used for covering the jewellery boxes and swords,

(f) Leather: A highly durable type of leather is prepared from the skin of sharks and rays,

(g) Artificial pearls: The silvery boney scales of cypnmids (a type of fish) are used in the manufacture of artificial pearls especially in France.

Employment

Development of fishing industry generates more employment opportu-nities.

Source of Income

The fishing industry has brought a lot of income to the farmers in particular and the country in general. Now we can talk about "Blue Revolution" (fish production) on the same lines as 'Green Revolution' (for producing enough food for all).

TYPES OF FISHERIES

There are two main types of fisheries: Inland fisheries and marine fisheries.

Inland or Fresh Water Fisheries

Inland fishery deals with the fishery aspects of waters other than marine water. Potentially, the vast and varied inland fishery resources of India are one of the richest in the world. They pertain to two types of waters, namely, the fresh and the brackish. The former includes the country's great river systems, an extensive network of irrigation canals, reservoirs, lakes, tanks, ponds, etc.

The estuaries, lagoons and mangrove swamps constitute the brackish type of water. In pisciculture (culture fisheries), which generally pertains to small water bodies, the fish seed has to be sown, tended, nursed, reared and finally harvested when grown to table size. In the case of capture fisheries, which pertain to the rivers, estuaries, large reservoirs, as well as big lakes, man has only to reap without having to sow some important edible fresh waterfishes of India.

TYPES OF BREEDING

According to the mode of breeding there are two categories, natural breeding and induced breeding.

Natural Breeding (Bundh breeding)

The natural bundhs are special types of ponds where natural water resource conditions are managed for the breeding of culturable fish. These bundhs are constructed in large low-lying areas to accumulate large quantity of rain water. These bundhs are having an outlet for the exit of excess rain water.

Induced Breeding

In artificial method of fertilization ova from the females and the sperms from the males are taken out by artificial mechanical process and the eggs are got fertilized by the sperms. Different methods are used for induced breeding. Here induced breeding by hormones method is briefly described. The gonadotropin hormone (FSH and LH) secreted by pituitary gland influences the maturation of gonads and spawning in fishes. In India, Khan (1938) successfully induced Cirrhinus mrigala to spawn by injecting mammalian pituitary hormone.

Composite Fish Farming

It is found that if few selected species of fish are stocked together in proper proportion in a pond, total production of fish is increased many times. This mixed farming is called composite farming. It has some advantage-compatible species do not harm each other, all available areas are fully utilised, no competition among different species is found and fish may have beneficial effect on each other. Catla catla, Labeo-rohita and Cirrhina mrigala are surface feeder, column feeder and bottom feeder respectively and are used for composite farming.

Marine Fisheries

Marine fishery deals with the fishery aspects of the sea water or ocean. Hilsa migrates from the sea to the river for breeding. Dr. Hora studied the migration of Hilsa.

FISH DISEASES CAUSED BY PARASITES AND PATHOGENS

Bacterial Diseases

Two bacterial diseases are very important.

(i) Abdominal dropsy of Carps is caused by Aeromonas punctuata.

(ii) Furunculoris of Salmons and trout's is caused by Aeromonas salminicida.

Viral Diseases

Economically most important is the viral haemorrhage septicaemia (VHS) of rainbow trouts.

Protozoan Diseases

Main protozoan diseases are caused by Costia, Myxobolus and Trypanosoma.

Fungal Diseases

The gill rot (branchyomyces) of carps involves the attack of Saprolegnia on the gills of carps.

Worm Diseases

Worms of four groups are parasites on fish. The flatworms (trematodes), tapeworms (cestodes), round worms (nematodes) and thorny-headed worms (acanthocephalans).

Common Ectoparasites

Two ectoparasites of fish are most important, the fish lice (Argulus, Lernaea and Ergasilus) and the fish leech (Piscicold). Both parasites weaken fish by feeding on its blood.

PHYTOGEOGRAPHY, CLIMATE, VEGETATION AND BOTANICAL ZONES OF INDIA

According to Campbell (1926), the main theme of plant geography is to discover the similarities and diversities in the plants and floras of the present and past found in widely separated parts of the earth.

Wulff (1943) states that Phytogeography is the study of distribution of plant species in their habitats and elucidation of origin and history of development of floras.

According to Croizat (1952), Phytogeography is the study of migration and evolution of plants in time and space.

Major Divisions of Phytogeography

There are two major divisions of Phytogeography:

(i) Descriptive or Static Phytogeography

(ii) Interpretive or Dynamic Phytogeography

Descriptive Phytogeography

This deals with the actual description of floristic or vegetational groups found in different parts of the world. Early plant geographers described floras and attempted to divide earth into floristic and botanical zones.

Interpretive or Dynamic Phytogeography

This deals with the dynamics of migration and evolution of plants and floras. It explains the reasons for varied distribution of plant species in different parts of the world. It is a borderline science involving synthesis and integration of data and concepts from several specialized disciplines like ecology, physiology, genetics, taxonomy, evolution, palaeontology and geology. Good (1931), Mason (1936), Cain (1944) and some others have pointed out the factors involved in the distribution of plants.

Lowerence (1951) has suggested the following thirteen modern principles of Phytogeography which are classified into four groups:

Principles concerning environment

1. The distribution of plants is primarily controlled by climatic conditions.
2. There has been variation in climate during geological history in the past which affected migration of plants.
3. The relations between land masses and seas have varied in the past. The large land masses split up to form new land masses or continents which separated and reoriented. Land bridges between continents acted as probable routes for migration of plant and animal species. The land bridges became submerged in sea with the passage of time and the possibility for migration of plants and animals from one continent to another disappeared for ever.
4. Soil conditions on plains and mountains of different land masses show secondary control on distribution of

vegetation. Halophytes, psammophytes, calcicols, calcifobs etc. have developed because of edaphic conditions.

5. Biotic factors also play important role in distribution and establishment of plant species.
6. The environment is holocentric, i.e., all environmental factors have combined effects on the vegetation of a place (Ale & Pank, 1939).

Principles concerning plant responses

7. Range of distribution of plants is limited by their tolerances. Each plant species has a range of climatic and edaphic conditions. Therefore, tolerance of a large taxon is the sum of tolerances of its constituent species.
8. Tolerances have a Genetic basis. The response of plants to environment is governed by their genetic makeup. Many of the crops through breeding and genetic changes have been made to grow in wider range of environmental conditions. In nature, hybrid plants have been found to have wider range of tolerances than their parents.
9. Different ontogentic phases have different tolerances. Different developmental stages of plants show different degree of tolerances, as for example seeds and mature plants are more tolerants to temperature and moisture variations than their seedlings.

Principles concerning the migration of floras and climaxes

10. Large scale migrations have taken place. The fossils and palaeoecological evidences reveal that large scale migrations of plants and animals have taken place during Mesozoic era and Tertiary periods.
11. Migration resulted from transport and establishment. In the process of migration plants are dispersed to new habitats through their propagules such as spores, seeds, bulbils etc., and there they are established if environmental

conditions are favourable. Plants grow and reproduce there and progeny perpetuates through ecological adjustments.

Principles concerning the perpetuation and evolution of floras and climaxes

12. Perpetuation depends first upon migration and secondly upon the ability of species to transmit the favourable variations to the progenies.
13. Evolution of floras and climaxes depends upon migration, evolution of species and environmental selections.

Distribution

On the basis of area of the earth surface occupied by the plants, the various taxa are categorized as under:

Wides

Plants widely distributed over the earth in definite climatic zones and the different continents are referred to as wides. Cosmopolitan is applied for wides but, in fact, no plant is cosmopolitan in real sense of the term. Taraxacum officinale and Chaenopodium album are the common examples of the wides. Plants of tropical regions are called Pantropical. The plants of very cold climate may not only be found in the arctic regions but also in alpine zone of mountains in tropical and subtropical regions. These are called arctic-alpine plants.

Endemics

A taxon whose distribution is confined to a given area is said to be endemic to that area. The taxon may be of any rank, although it is usually at a family level or below, and its range of distribution may be wide, spanning an entire continent, or very narrow covering only a few square metres. The concept of endemism is important because in the past the formulation of biogeographic regions was based on it.

The limits of a region are determined by mapping the distributions of taxa; where the outer boundaries of many taxa occur, a line delimiting? a biogeographic region is drawn. Major regions are still determined as those that have the most endemics or stated another way, those that share the fewest taxa with other regions. As regions are further broken down into subdivisions, they will contain fewer unique taxa.

This has been criticized because it assumes that species ranges are stable, which they are not. An alternative method of determining biogeographic regions involves calculating degrees of similarity between geographic regions. The concept of endemic distribution of plants was put forth by A.P. de Candolle (1813). Engler (1882) suggested two categories of endemic forms; Palaeo-endemics which are survivors of ancient forms and indigenous or native forms which are confined to a particular ocahty. According to area of distribution, the species may be continental endemics (restricted to a continent, endemic to a country, provincial, regional or local endemics (restricted to valley, hills, islands, etc.).

Now the endemic species have been grouped into the following categories:

Relics or Palaeoendemics

They are the survivors of once widely distributed ancestral forms, for example, Ginkgo biloba (restricted to China and Japan), Sequoia sempervirens (confined to coastal valleys of California, U.S.A.). Agathis australis, Metasequoia (Confined to Single valley in China). These species are called Palaeoendemics or epibionts. A great majority of the endemic species belonging to this type have many fossil relatives. They are also called living fossils. Because of little variability the endemics are adapted only to a particular environment and even if they reach new areas, they fail to establish themselves in new environment.

Neoendemics

The other endemics may be modem species which have had not enough time for occupying a large area through migration. They are called neoendemics. There are several such genera which are widely endemic or few species of which are endemic.

Neoendemics show good variability and have many biotypes, grow in diverse habitats and have wide tolerance for habitats.

Some of the well known endemic genera in Indian flora are Mecanopsis (Papaveraceae) Chloroxylon swietenia (Flindersiaceae, formerly Rutaceae). Catenaria and Butea (Papilionaceae) Caesulia (Compositae), Petalidium (Acanthaceae), etc. Eletteria repens (Zingiberaceae) Piper longum (Piperaceae), Piper nigrum (Piperaceae), Ficus religiosa (Moraceae), Shorea robusta (Dipterocarpaceae), Venda caerulea (Orchidaceae), Salmalia malabarica (Bombacaceae) Eleusine coracana (Grammeae) are the well known endemic species of Indian flora. There are some special terms to designate the quality of these endemics, viz. Local endemics which are found in small land features, progressive endemics which tend to spread with time retrogressive endemics in which case the area of distribution is contracting and micro-endemics (i.e., the endemics of lower groups).

Pseudo endemics

These endemics arise due to mutation in existing population at a particular place. These pseudo endemics or mutants may or may not persist for long in the particular area where they originate. Endemism results from the failure on the part of species to disseminate its seeds fruits spores or propagules because of existence of great barriers like mountains, oceans and large deserts. The oceanic islands which are isolated from rest of the world by large expanses of water abound in endemic species and water barrier checks the migration of those species outside their original habitat.

Discontinuous Distribution

When plants occur at two or more distant places of the world which are separated by overland's or oceans hundreds or thousands of kilometres apart. Such a distribution is called discontinuous or disjunct distribution. Three genera Nothofagus, Jovellona and a for example are found in parts of South America, South Africa and Australia which are -paraded by vast oceans.

The significant phytogeographical causes for discontinuous distribution are as follows:

(i) The species might have evolved at more than one place and they failed to migrate outside their original habitats because of barriers.

(ii) The species which were once widely distributed in the past disappeared from certain areas and are now surviving in some distant pockets.

(iii) The climate may also be a factor for discontinuity in distribution of species. Plants having specific climatic requirements are found in widely separated areas with similar environmental conditions, as for example, plants of arctic regions are also found in alpine zone of high mountains in tropics and subtropics. Salix and Silen species show discontinuous distribution in arctic-alpine regions.

Theories of Discontinuous Distribution

Theory of Land Bridge

According to this theory, land bridges occurring in between the separated continents are believed to have helped in the migration of various taxa from one continent to the other. Uniform distribution of plants and animals in different parts of the world during Palaeozoic era is believed to have been due to those land bridges. With the passage of time the land bridges became submerged in sea and the connections between the various continents snapped beyond the dispersal capacity of organisms resulting thereby the discontinuity in the distribution.

Theory of Continental drift

The theory of continental drift was propounded by Wegner (1912 1924) According to him the whole land- mass of the world was a single super continent during Palaeozoic era. He named it as Pangaea. That super continent was surrounded by sea on all the sides which was named Panthalassa. During Mesozoic, Pangaea split up into two large landmasses; Laurasia in the north and Gondwanaland in south.

The two landmasses were separated by Tethys Sea. Du Toit (1937), however, suggested that Laurasia and Gondwanaland existed from the very beginning. The two large landmasses having characteristic flora and fauna broke up into new landmasses called continents. Laurasia gave rise to Eurasia, Greenland and North America and similarly Gondwanaland gave rise to South America, Africa, India, and Polynesia, Australia Antarctica etc.

About 135 million years ago reorientation of continents began. The continents were drifted apart by the oceans. This is called Continental Drift. The occurrence of Dinosaurs and many fossil plants lend support to the existence of Laurasia and Gondwanaland. With the separation of continents the distribution areas of several plant and animal species got separated and gave rise to discontinuous distribution areas.

Factors Affecting Distribution of Species

Several factors are known to affect the geographical distribution of plant species, some of which are as follows:

Geological history and distribution

The place where a species first originated is called its centre of origin. Evolution of species is a slow but continuous process. Some of the species in present day flora are quite old while a great majority of them are recent in origin.

The process of species differentiation involves:

(i) Hybridization between the related species as well as mutation and

(ii) The natural selection of the hybrid and mutant populations.

In the selection process not all the hybrids and mutants are selected by nature and only the fittest individuals which find the habitat conditions within their ecological amplitudes are selected and the individuals least fit are eliminated. Changing climate has also played important role in the origin of new species. In the course of evolution several old species became extinct, some of which can be found even today as fossils. The fossils provide direct evidence for the existence of various taxa in the past.

Age and Area Hypothesis

This hypothesis was proposed by J. W. Willis (1915) on the basis of his extensive studies of geographical distribution of certain plant species in tropics. On the basis of his findings Willis postulated that the species which evolved earlier occupy greater areas than those which appeared later in the evolutionary sequence. According to this hypothesis, the frequency of a species over an area is directly proportional to its age in scale of evolution and age of species is directly related with the area of its distribution.

Thus a small area of distribution of a species will indicate its relative young age. Willis has quoted several examples such as Impatiens, Primula, Gentiana, Rhododendron in support of his hypothesis. Genus Coleus may be quoted here as an example in support of this hypothesis. There are two species of Coleus namely C. elongatus and C. barbatus.

The former species is endemic while the latter is widely distributed. On the basis of areas under distribution of these species Willis considered C. elongatus less evolved and derived from C barbalins. Willis has also pointed out that the majority of endemics are found to be members of large and successful genera. The age and area hypothesis, however, is not universal and it has been criticized by many.

Migration

The newly evolved species starts migration to new areas and side by side it undergoes further evolutionary changes. The dispersal of germules and propagules is brought about by several agencies like wind, water, glaciers, insects, animals, even man. The dispersal is followed by ecasis. Migration may be adversely affected and sometimes even totally stopped by some factors called migration barriers. Barriers in the dispersal of species may be classified as ecological or environmental and geographical.

The climate, an ecological barrier, plays important role in distribution and establishment of species. Unsuitable climatic condition or change of climate in particular area forces the species to migrate from one place to another and the failure of some species to migration leads them to gradual extinction. Besides climate, there are geographical barriers, as for example, high mountains, vast oceans or deserts.

The fresh water plants, for example, cannot be dispersed across oceans if their propagules are suitable only for fresh water dispersal and similarly germules or propagules of land plants from one country cannot reach other country separated by vast oceans and mountains. Species are called natives of the place of occurrence if they originated there. Outside the area of its origin, the species is referred to as exotic. Exotic species reach new area through migration. If any species is introduced intentionally in new area by man then it is called introduced species.

Ecological amplitudes and distribution

Environmental conditions not only influence the life and development of plants but also determine the presence or absence, vigour or weakness and relative success or failure of various plants in a particular habitat. Each plant species of a community has a definite range of tolerance towards physical and biological environment of the habitat. This is referred to as ecological amplitude. The presence of species at a particular place, no doubt, indicates that the environmental conditions of that habitat are within its ecological amplitude but the absence of a species from one place does not necessarily indicate that the environment is not suitable for that species.

The ecological amplitude is governed by genetic set up of the species concerned and thus different species have different ecological amplitudes which may sometimes overlap only in certain respects. Further, some species may occur at different geographical regions as and when the conditions fall within their ecological amplitudes. As for example, some plants of temperate region say conifers, may also be found in alpine zone of high mountains in tropical and subtropical regions.

The other consideration in ecological amplitude as a factor in plant distribution is its change with time. In sexually reproducing plants the hybridization between related species results in offspring's with new genetic composition. With the change of environment the plant species also make adjustments with new environment by shifts in their ecological amplitudes facilitated by changes in the genotype. Within a species there may occur several genetically different groups of individuals (populations) which are adjusted to particular set of ecological conditions.

These populations are called ecotypes or ecological races or ecological populations. In Euphorbia thymifolia, for example, there are two major populations-one is calcium loving or calcicole and the other type is calcium hating or calcifuge. Similarly ecological races of Xanthium strumarium and Ageratum conyzoides differ in the photoperiodic requirements. The existence of ecotypes within the species widens the area of its geographical distribution.

KNOWLEDGE OF PHYTOGEOGRAPHY

Many other names of botanists who contributed to the knowledge of phytogeography in the first half of the 19th century could be mentioned. One has to remember that from the time of Linnaeus to the time of Darwin there was a tremendous amount of geographical exploration that often included botanical research. It is true that this was very largely systematic and economic but without taxonomy there can be no development of plant geography. Collections poured in from all over the world and were described in "floras" and monographs. Gardens, botanic and horticultural, were enriched and systems of classification were gradually improved.

The work of botanists, whether in taxonomy or in phytogeography, was then essentially descriptive and classificatory. In plant geography, however, there had been some advances on this somewhat static position in that correlations were found between ranges and environmental factors. The theory of evolution was, however, not generally accepted till after the publication of Darwin *Origin of Species* in 1859. The influence of evolutionary theory in explaining the facts of plant geography very speedily became apparent in the writings of botanists.

It is also worth noting that Darwin considered biogeography as of very great importance in supporting his theory of evolution by natural selection. He devotes two chapters to "Geographical Distribution" in the Origin of Species. The development of plant geography was very great during the second half of the 19th century. The flora and vegetation of many countries were explored and described and many of the problems that arise in attempting to explain their origin were often clearly stated.

Only a few outstanding names can be mentioned and that of J. D. Hooker is foremost because of his work "in the field" and his extensive publications in this subject. Hooker, as Assistant Surgeon and Botanist, accompanied James Clark Ross in the *Erebus* and *Terror* expedition to "Antarctica" and collected and studied the flora in Madeira, Cape Verde Islands, St. Helena, Kerguelen Island, Tasmania, The Falklands, Hermite Island, New Zealand, and the Cape. His journey to the eastern Himalaya and botanizing in Sikkim and Assam occupied the whole of 1848 and much of 1849. In 1860, he visited Syria and Palestine, in 1871 Morocco, and in 1877 North America on botanical expeditions. A full account of the phytogeographical researches of Sir Joseph Dalton Hooker was published in 1953.

Partly contemporaneous with J. D. Hooker were the great German botanists — A. Grisebach, A. Engler and O. Drude with their text-books and other comprehensive works on plant geography. The important series of monographs by various authors edited by Engler and Drude under the general title *Die Vegetation der Erde* covered many countries of the world. Karsten und Schenck edited the volumes of *Vegetationsbilder* Jena, 1904 to 1944, 1, 26.

Since 1900 a number of general books on plant geography have been published. The following are given in the bibliography and have been consulted in preparing the accounts of modern methods and results that follow: H. Solms-Laubach, Graebner, Hayek, Campbell, Wulff, Cain, Good, Croizat, and Dansereau.

Special mention must be made of the improvements in plant geography resulting from the rise of ecology and the more recent advances in physiological ecology. The great work of A. F. W. Schimper, *Pflanzengeographie auf physiologischer Grundlage*, Jena 1898, with its English translation *PlantGeography upon a physiological basis*, by W. R. Fisher, revised and edited by P. Groom and I. B. Balfour, Oxford 1903, had a tremendous influence in stimulating interest and research in the subject. Some of Schimper's conclusions, as those on xeromorphism, have been strongly criticized and have to be modified as a result of more evidence though it is interesting to note that more recently still it has been shown that some of the criticisms were too extreme.

A third edition of Schimper *Pflanzengeographie*, by F. C. von Faber, was published at Jena in 1935 in two volumes. A textbook by E. Warming was originally published in Danish, in 1895, under the title *Plantesamfund*, with German editions in 1896 and 1902. What is described as "practically a new work" by E. Warming assisted by M. Vahl, based on *Plantesamfund*, appeared in 1909 as *Oecology of Plants, an introduction to the study of plant-communities*, Oxford. There were later German editions of which the fourth by E. Warming and P. Graebner has the title *Lehrbuch der okologischen Pflanzengeographie*, Berlin 1930- 1933. While Warming's first book quoted above is ecological rather than

p hytogeographical, the last edition is wider in its outlook. E. Rubel's scheme for the delimitation and nomenclature of plant communities is also of phytogeographical importance. The full account was published as *Pflanzengesellschaften der Erde*, Bern-Berlin, 1930. Like the works of Schimper and Warming, it has an ecological basis.It is worth recording that the text-books on plant geography and closely related plant ecology mentioned above contain numerous bibliographical references.

The boundary between ecology and phytogeography is frequently passed in many of the papers published in ecological journals such as the *Journal of Ecology*, *Ecology*, *Oikos*, and *Vegetationsbilder*. The publication *Pflanzenareale*, with range maps and explanatory text, is more definitely phytogeographical but has apparently ceased publication.The use of palaeobotanical evidence in plant geography can be gauged from Wulff's 1932-1944 publications already noted and from Seward book *Plant-Life through the Ages*, Cambridge, 1931.

There are also the very important works of Reid and Chandler and Chaney, and the publications referred to in Cain Recently there has been the introduction of cytogenetical data into the realm of plant geography. There is no doubt that researches on the cytology and breeding phenomena of plant species will become of increasing importance in tracing the history of their ranges. At present the known facts are meagre relative to the number of species in even poor floras, while cytogenetic investigation of the rich floras of the tropics has been little more than commenced.

PHYLOGEOGRAPHY: STUDY OF THE HISTORICAL PROCESSES

Phylogeography is the study of the historical processes that may be responsible for the contemporary geographic distributions of individuals. This is accomplished by considering the geographic distribution of individuals in light of genetics, particularly population genetics.

This term was introduced to describe geographically structured genetic signals within and among species. An explicit focus on a species' biogeography/biogeographical past sets phylogeography apart from classical population genetics and phylogenetics.

Past events that can be inferred include population expansion, population bottlenecks, vicariance and migration. Recently developed approaches integrating coalescent theory or the genealogical history of alleles and distributional information can more accurately address the relative roles of these different historical forces in shaping current patterns.

Development

The term phylogeography was first used by John Avise in his 1987 work *Intraspecific Phylogeography: The Mitochondrial DNA Bridge Between Population Genetics and Systematics*. Historical biogeography addresses how historical geological, climatic and ecological conditions influenced the current distribution of species. As part of historical biogeography, researchers had been evaluating the geographical and evolutionary relationships of organisms years before. Two developments during the 1960s and 1970s were particularly important in laying the groundwork for modern phylogeography; the first was the spread of cladistic thought, and the second was the development of plate tectonics theory.

The resulting school of thought was vicariance biogeography, which explained the origin of new lineages through geological events like the drifting apart of continents or the formation of rivers. When a continuous population (or species) is divided by a new river or a new mountain range (i.e., a vicariance event), two populations (or species) are created. Paleogeography, geology and paleoecology are all important fields that supply information that is integrated into phylogeographic analyses.

Phylogeography takes a population genetics and phylogenetic perspective on biogeography. In the mid-1970s, population genetic analyses turned to mitochondrial markers. The advent of the polymerase chain reaction (PCR), the process where millions of copies of a DNA segment can be replicated, was crucial in the development of phylogeography.

Thanks to this breakthrough, the information contained in mitochondrial DNA sequences was much more accessible. Advances in both laboratory methods (e.g. capillary DNA sequencing technology) that allowed easier sequencing DNA and computational methods that make better use of the data (e.g. employing coalescent theory) have helped improve phylogeographic inference.

Early phylogeographic work has recently been criticized for its narrative nature and lack of statistical rigor (i.e. it did not statistically test alternative hypotheses). The only real method was Alan Templeton's Nested Clade Analysis, which made use of an inference key to determine the validity of a given process in explaining the concordance between geographic distance and genetic relatedness. Recent approaches have taken a stronger statistical approach to phylogeography than was done initially.

Example

Climate change, such as the glaciation cycles of the past 2.4 million years, has periodically restricted some species into disjunct refugia. These restricted ranges may result in population bottlenecks that reduce genetic variation. Once a reversal in climate change allows for rapid migration out of refugial areas, these species spread rapidly into newly available habitat. A number of empirical studies find genetic signatures of both animal and plant species that support this scenario of refugia and postglacial expansion. This has occurred both in the tropics (where the main effect of glaciation is increasing aridity, i.e. the expansion of savanna and retraction of tropical rainforest) as well as temperate regions that were directly influenced by glaciers.

Phylogeography and conservation

Phylogeography can help in the prioritization of areas of high value for conservation. Phylogeographic analyses have also played an important role in defining evolutionary significant units (ESU), a unit of conservation below the species level that is often defined on unique geographic distribution and mitochondrial genetic patterns.

A recent study on imperiled cave crayfish in the Appalachian Mountains of eastern North America demonstrates how phylogenetic analyses along with geographic distribution can aid in recognizing conservation priorities. Using phylogeographical approaches, the authors found that hidden within what was thought to be a single, widely distributed species, an ancient and previously undetected species was also present. Conservation decisions can now be made to ensure that both lineages received protection. Results like this are not an uncommon outcome from phylogeographic studies.

An analysis of salamanders of the genus *Eurycea*, also in the Appalachians, found that the current taxonomy of the group greatly underestimated species level diversity. The authors of this study also found that patterns of phylogeographic diversity were more associated with historical (rather than modern) drainage connections, indicating that major shifts in the drainage patterns of the region played an important role in the generation of diversity of these salamanders. A thorough understanding of phylogeographic structure will thus allow informed choices in prioritizing areas for conservation.

Comparative phylogeography

The field of comparative phylogeography seeks to explain the mechanisms responsible for the phylogenetic relationships and distribution of *different* species. For example, comparisons across multiple taxa can clarify the histories of biogeographical regions. For example, phylogeographic analyses of terrestrial vertebrates on the Baja California peninsula and marine fish on both the Pacific and gulf sides of the peninsula display genetic signatures that suggest a vicariance event affected multiple taxa during the Pleistocene or Pliocene.

Phylogeography also gives an important historical perspective on community composition. History is relevant to regional and local diversity in two ways. One, the size and makeup of the regional species pool results from the balance of speciation and extinction. Two, at a local level community composition is influenced by the interaction between local extinction of species' populations and recolonization. A comparative phylogenetic approach in the Australian Wet Tropics indicates that regional patterns of species distribution and diversity are largely determined by local extinctions and subsequent recolonizations corresponding to climatic cycles.

Phylogeography integrates biogeography and genetics to study in greater detail the lineal history of a species in context of the geoclimatic history of the planet. An example study of poison frogs living in the South American neotropics (illustrated to the left) is used to demonstrate how phylogeographers combine genetics and paleogeography to piece together the ecological history of organisms in their environments. Several major geoclimatic events have greatly influenced the biogeographic distribution of organisms in this area, including the isolation and reconnection of South America, the uplift of the Andes, an extensive Amazonian floodbasin system during the Miocene, the formation of Orinoco and Amazon drainages, and dry"wet climate cycles throughout the Pliocene to Pleistocene epochs.

Using this contextual paleogeographic information (paleogeographic time series is shown in panels A-D) the authors of this study proposed a null-hypothesis that assumes no spatial structure and two alternative hypothesis involving dispersal and other biogeographic constraints (hypothesis are shown in panels E-G, listed as SMO, SM1, and SM2). The phylogeographers visited the ranges of each frog species to obtain tissue samples for genetic analysis; researchers can also obtain tissue samples from museum collections.

The evolutionary history and relations among different poison frog species is reconstructed using phylogenetic trees derived from molecular data. The molecular trees are mapped in relation to paleogeographic history of the region for a complete phylogeographic study. The tree shown in the center of the figure has its branch lengths calibrated to a molecular clock, with the geological time bar shown at the bottom. The same phylogenetic tree is duplicated four more times to show where each lineage is distributed and is found (illustrated in the inset maps below, including Amazon basin, Andes, Guiana-Venezuela, Central America-Chocó).

The combination of techniques used in this study exemplifies more generally how phylogeographic studies proceed and test for patterns of common influence. Paleogeographic data establishes geological time records for historical events that explain the branching patterns in the molecular trees. This study rejected the null model and found that the origin for all extant Amazonian poison frog species primarily stem from fourteen lineages that dispersed into their respective areas after the Miocene floodbasin receded. Regionally based phylogeographic studies of this type are repeated for different species as a means of independent testing. Phylogeographers find broadly concordant and repeated patterns among species in most regions of the planet that is due to a common influence of paleoclimatic history.

Human phylogeography

Phylogeography has also proven to be useful in understanding the origin and dispersal patterns of our own species, *Homo sapiens*. Based primarily on observations of skeletal remains of ancient human remains and estimations of their age, anthropologists proposed two competing hypotheses about human origins.

The first hypothesis is referred to as the Out-of-Africa with replacement model, which contends that the last expansion out of Africa around 100,000 years ago resulted in the modern humans displacing all previous *Homo* spp. populations in Eurasia that were the result of an earlier wave of emigration out of Africa. The multiregional scenario claims that individuals from the recent expansion out of Africa intermingled genetically with those human populations of more ancient African emigrations. A phylogeographic study that uncovered a Mitochondrial Eve that lived in Africa 150,000 years ago provided early support for the Out-of-Africa model.

While this study had its shortcomings, it received significant attention both within scientific circles and a wider audience. A more thorough phylogeographic analysis that used ten different genes instead of a single mitochondrial marker indicates that at least two major expansions out of Africa after the initial range extension of *Homo erectus* played an important role shaping the modern human gene pool and that recurrent genetic exchange is pervasive. These findings strongly demonstrated Africa's central role in the evolution of modern humans, but also indicated that the multiregional model had some validity. These studies have largely been supplanted by population genomic studies that use orders of magnitude more data.

In light of these recent data from the 1000 genomes project, genomic-scale SNP databases sampling thousands of individuals globally and samples taken from two non-Homo sapiens hominins

(Neanderthals and Denisovans), the picture of human evolutionary has become more resolved and complex involving possible Neanderthal and Denisovan admixture, admixture with archaic African hominins, and Eurasian expansion into the Australasian region that predates the standard out of African expansion.

Phylogeography of viruses

Viruses are informative in understanding the dynamics of evolutionary change due to their rapid mutation rate and fast generation time. Phylogeography is a useful tool in understanding the origins and distributions of different viral strains. A phylogeographic approach has been taken for many diseases that threaten human health, including dengue fever, rabies, influenza and HIV. Similarly, a phylogeographic approach will likely play a key role in understanding the vectors and spread of avian influenza (HPAI H5N1), demonstrating the relevance of phylogeography to the general public.

Phylogeography of languages

Phylogeographic analysis of ancient and modern languages has been used to test whether Indo-European languages originated in Anatolia or in the steppes of Central Asia. Language evolution was modeled in terms of the gain and loss of cognate words in each language over time, to produce a cladogram of related languages. Combining those data with known geographic ranges of each language produced strong support for an Anatolian origin approximately 8000–9500 years ago.

AIMS OF PLANT PHYTOGEOGRAPHY AND GEOGRAPHY

We have briefly outlined the history, scope, and aims of plant geography and have given some selected details of the work on or linked to phytogeography in major phytochoria of the earth. The various realms and regions have been treated somewhat unequally and differently. This was partly done deliberately to illustrate different "vistas," different methods of approach, and different kinds of emphasis.

The subject is so vast, has so many "side-lines," and is once again, with new outlooks, so dynamic that arbitrary limits had to be set. This is the excuse for having to leave out much of interest and importance. There are many subjects within phytogeography that have special problems and some of these have been selected for condensed consideration under a number of headings.

Kinds of Ranges

Ranges of species are of various kinds, though there are intermediates between any classes one makes. Ranges may be exceedingly wide even almost cosmopolitan, as for *Pteridium aquilinum,* or very small as for *Ramonda (Jankaea) heldreichii;* they may be relatively continuous, as for *Pinus halepensis,* or markedly discontinuous, as for *Convolvulus nitidus;* they may show clinal structure, as in *Ajuga chamaepitys,* or they may not, as in *Arbutus unedo;* they may be divisible into subspecific ranges, as in Silene vulgaris, or there may be no marked geographical correlations with intraspecific variation, as in *Fritillaria meleagris;* they may be restricted to a given geographical area when the species is said to be endemic to the area, as *Petromarula pinnata* is endemic to Crete, or they may extend beyond a geographical area, as do the vast majority of the species of the British flora.

Two general statements must be made: the different kinds of ranges just enumerated for species occur, with slight modifications of wording, in connection with taxa of higher rank than species and our data for past ranges as based on reliable fossil evidence is, for the angiosperms in particular, relatively meagre. We must also note that "continuity of range" means only that the species (or other taxon) occurs without wide geographical breaks but ignoring ecological breaks.

If there be no major problem as to dispersal of disseminules from population to population the range is considered continuous in a wide sense. There is, however, every intermediate between isolation of populations within a species, that is, separation of groups of individuals within a phytochorion so that one cannot interbreed with another because of external barriers, and wide geographical isolation. Some of the problems of discontinuous ranges are well dealt with by Cain, and the statistical study of wide and restricted ranges is the basis of much of Willis's work on "age and area". The importance of clines is discussed by Huxley, though mainly from the zoological standpoint. Corresponding to clines in taxonomy and population studies are ecotones in ecology. Clines are defined as character gradients within groups while ecotones are the transitions between adjoining plant communities.

It is very doubtful if polytopism (the origin of a taxon independently at more than one locality) occurs except at a low taxonomic level, assuming, of course, that the taxonomy be sound. We have to accept that most taxonomic entities have had one place of origin. It is sometimes claimed that the centre of a range, or the place of greatest frequency or of maximum variability or of lushness of development indicates the area of origin more or less precisely. Certainly all of these facts have to be taken into account but none of them is conclusive.

They must all be considered together and with the independent conclusions of taxonomic affinities as based on modern synthetic taxonomy. There are, however, many facts concerned with range that have evolutionary significance. Variation at the margins of ranges is frequently different from that near the centre. Often this can be correlated with different environmental factors and the action of natural selection is plain, as with *Silene martitima* subsp. *islandica.*

The division between species and subspecies is not sharp and there seems circumstantial evidence from the study of ranges (combined with taxonomic data) that subspecies can give rise to fully isolated species. Endemics are defined as species (or other taxa) limited in present range to a given geographical area. Some endemics are such because they are of relatively recent origin, presumably within their present range, and have not yet had time to extend over all their area of tolerance. These are neo-endemics and are often microspecies (or microtaxa).

At the other extreme there are the palaeo-endemics which originated long ago but have either never been able to extend their ranges or have gradually "lost ground" from competition with other species, often correlated with environmental changes for which their sum total of biotype diversification is unsuited except in their now restricted endemic range. This is the explanation of what is sometimes referred to as species senescence. Taxa do die out, as the fossil record proves, but they do not become "old" in the sense of old age of individuals.

Rare and Relict Species

The term "rare" is relative. It may indicate a species that has a very small range but is common within that range, or a species with a more or less wide general range within which it is represented by few individuals, or, in the extreme, it may be a species with a small range with few individuals within that range. For the broader problems of phytogeography we usually mean a species with a small range or at least with a small approximately continuous range.

Rare species may be restricted in their ranges either because they are young and have not had time to spread or because their characters (expressed in one or in more than one biotype) are not suited for any environment outside the narrow range to which access has been obtained or they may be relicts, that is, they have ranges that are smaller than formerly.

There seems no valid reason for supposing that new species are being formed in smaller numbers than at any time, say, since the beginning of Tertiary times. Indeed, with the making of new environments by man, with the greatly increased plant dispersal by man, and by the consequently increased chances of hybridization it is probable that new kinds of plants are appearing at an increasing rate, though how many of these may be acceptable taxonomic species is another matter. On the other hand, palaeobotanical research proves that taxa become extinct.

Unfortunately, we know little about the causes of extinction of taxa; indeed, we know far too little, in any systematic manner, regarding the death of individuals in nature. Two general facts have to be used by the plant geographer: that organic evolution has continued throughout plant history and that environments are are continually changing. Comparisons between phylogeny and ontogeny may be misleading.

Thus it is probably incorrect to talk about the wear-out or old age of a species as similar to senescence in an individual. The most successful species are those that meet with the fewest limiting factors for completing their life cycles over the widest ranges and are able to disperse over these ranges.

The environment, however, may change — as by the on-coming of a glacial epoch or increased aridity, or the appearance of better equipped biotic competitors — and the species may be so specialized, may have so few biotypes, or may have too little potentiality for producing suitable mutations that it cannot survive or at least maintain its existing range.

It may be able to "migrate" or it may be exterminated, or it may indefinitely continue to exist very locally as a rare relict. Space will not allow the enumeration of actual examples. Such are given by Griggs, Stebbins, Cain, Wildeman, and Matvejev.

Vicarious Species

The comparison of taxa that have been thoroughly studied often shows that taxonomically related varieties, species, or genera have distinct nonoverlapping ranges and these can sometimes be clearly correlated with different environments. The ranges may be more or less contiguous or discontinuous. Vierhapper attempted to distinguish between vicarism and pseudovicarism, the former when the nearly related "Sippen" (or as we should now say "taxa") have originated in the areas or formations from a common ancestor, the latter when one of these conditions does not hold or both do not hold.

He introduced the word "vicariads" for the members of a pair of vicarious taxa and notes that they may be separated horizontally (or geographically), altitudinally, ecologically, or seasonally (or temporarily). The pseudovicariads are probably a mixture: either they are not very closely related or it is uncertain that they should be considered derived from a very near common ancestor or it is more or less certain that they represent convergent evolution, and often they belong to different sections of a genus.

It is rather doubtful if one can reasonably speak of vicarious families and tribes in a very strict sense and even some of the supposedly vicarious genera may be questioned. It is at, or below, the species level that vicarism can best be studied from the phytogeographical and evolutionary points of view. There are fairly numerous pairs of closely related species of which one is found in eastern North America and the other in Europe.

Examples are: *Vallisneria americana* and *V. spiralis, Anemone quinquefolia* and *A. nemorosa, Maianthemum canadense* and *M. bifolium,* and Scrophularia marilandica and S. nodosa. Examples of altitudinal vicariads are Myosotis silvatica and M. alpestris, Centaurea pseudophrygia and C. plumosa, Trifolium pratense and T. nivale, Soldanella major and S. hungarica, etc., and quite a marked proportion of high mountain plants in Crete and Greece could be quoted as examples by comparison with lowland congeners.

Ecological vicariads may be correlated with different substratum conditions (degree of acidity, water content, chemical or physical nature), as *Stachys palustris* and *S. silvatica, Lotus major* and *L. corniculatus, Geum rivale* and *G. urbanum, Gentiana clusii* and *G. kochiana, Rhododendron hirsutum* and *R. ferrugineum.* Other limiting factors are temperature and light and there is undoubtedly interaction of factors often involved in determining ranges of vicariads.

Vicariads have usually been paired off as a result of taxonomic and phytogeographical or ecological studies. It is being realized that they can throw much light on evolution when more detailed researches are made on them. Love says that the fundamental difference between true and false vicariads is that the former penetrated into their areas prior to their successive morphological and genetical differentiation while the latter differentiated before their dispersal to the new territory. He rightly stresses the need for cyto-genetical researches on supposedly vicarious pairs of taxa and shows, mainly on chromosome number and morphology, that some that have been accepted as vicariads are pseudo-vicariads, as *Zostera marina* and *Z. stenophylla, Gentianella procera* and *G. detonsa,* and *Glyceria grandis* and *G. maxima,* while *Populus tremula* and *P. tremuloides* and *Scirpus (Schoenoplectus) lacustris* and *S. acutus* are to be retained as true vicarious pairs.

The comprehensive study of the bladder campions (*Silene maritima* and *S. vulgaris)* by Marsden-Jones and Turrill has shown something of the complexity of the taxonomic, ecological, and evolutionary relationship of pairs of species. The two species, at least in their typical subspecies as found in the British Isles, are ecological vicariads. They have the same chromosome numbers and can cross reciprocally to produce fertile offspring but their ranges are different, though they overlap, and their ecological distribution is, with few exceptions, quite different.

As populations, again with few exceptions, they keep distinct. Yet within each, and especially within *S. vulgaris,* considering the whole of their ranges there are vicariads within the subspecies, for example, *S. vulgaris* subsp. *vulgaris,* subsp. *glareosa,* and subsp. *alpina.* Moreover, *S. vulgaris* subsp. *alpina* might well, on definition, be considered pseudovicarious with *S. maritima* subsp. *maritima* and as showing quite marked evolutionary convergence.

Area Hypothesis

An important view was put forward by J. C. Willis in 1915 and dealt with fully in his book *Age and Area*, Cambridge, and in other publications. Without qualifications, this states that the range of a species is determined by the age of the species, in the sense that a large range indicates an old age and conversely a small range a recent origin. Willis, partly to meet criticisms, hedged round his expression of "the rule" so that it became unworkable.

Thus he says: "The area occupied at any given time, in any given country, by any group of allied species at least ten in number, depends chiefly, so long as conditions remain reasonably constant, upon the ages of the species of that group in that country, but may be enormously modified by the presence of barriers such as seas, rivers, mountains, changes of climate from one region to the next, or other ecological boundaries, and the like, also by the action of man, and by other causes."

It has been found by the present writer and others that it is only by breaking away from the limitations imposed by this "expression" that one can test for any value in the general hypothesis that on the whole a larger range is a criterion of greater age in a given country. The main criticisms of the hypothesis have been that it fails to distinguish new species from "old," that limiting factors do not cancel out in groups compared, and that species formation has a number of "causes" of which sudden large mutation is not so important as Willis believes.

On the other hand, there is no doubt that the hypothesis is useful in that it directs attention to the time factor in range formation and that its application does sometimes explain existing ranges. Further, attention will have to be paid by phytogeographers to many of the questions Willis asks, particularly in a later book.

Hemispherical Ranges

The tropical belt separates a North Temperate from a South Temperate zone. While the floras of these two zones are very largely different, especially in species, genera, and predominance of tribes or families, they have some taxa in common, those round about the generic level being of particular phytogeographical importance. Both floristic resemblances and differences raise problems connected with what has been called "bipolar distribution" but had better be known as "bihemispherical ranges." It is true that there are mountain ranges, particularly in America and Tropical Africa, with a main north to south direction and which might serve as a highway for migration of a number of temperate taxa across the tropics. One has, however, to remember that while attitude affects temperature and precipitation the factors of photoperiodism remain and their influence on north to south (or the reverse) extension of ranges has been largely ignored and, indeed, we have little knowledge on this subject which is one that requires experimental investigation.

A second, and major, difficulty at arriving at any valid conclusion as to the history of present-day bihemispherical ranges is the meagre palaeobotanical evidence available. If the occurrence in Tertiary deposits of the Northern Hemisphere of what are now taxa limited to the Southern Hemisphere be accepted, and the evidence for this is stronger than it was, then the postulated place of origin of such families as the *Proteaceae* need not be restricted to southern latitudes.

That evolutionary convergence occurs is frequently demonstrated in detailed taxonomic studies but most often it concerns one or a few characters and not the gamut of organs. Polytopy, the origin of taxa in more than one place independently, is possible, indeed sometimes probable, at lower taxonomic levels but the chances of its occurring are proportionally less the greater the number of differential common characters involved.

It is usually unwise to fall back on polytopism to explain discontinuity of generic ranges unless the taxonomy has been thoroughly revised by modern synthetic methods. Moreover, polytopy may only push the problem back a stage, so to speak, and not solve it. Thus, if one said *Empetrum* arose independently in the northern and southern hemispheres, the question of how the ancestor or ancestors attained discontinuous ranges takes the place of the original problem.

Leaving aside the possibility of occasional polytopy, there have been two main theories regarding bihemispherical ranges: that the taxa concerned arose in the northern hemisphere and extended southwards or that they arose in the southern hemisphere and extended their ranges northwards. At present, the main land masses are in the northern hemisphere and the older view, ably supported by Thiselton-Dyer, is that "all the great assemblages of plants which we call floras seem to admit of being traced back at some time in their history to the northern hemisphere."

It is, he notes, "easy on this supposition to account for their possession of common characters which, in their widely scattered southern distribution is not readily explained on other grounds."

Similar views have been supported by various botanists and also, on the zoological side, by some zoologists.

In marked contrast are the views of Camp and Croizat, amongst others. Camp, for example, considers the ranges of 103 plant families with restricted territories and shows their concentration in the southern hemisphere. He concludes that most of these families originated in the southern hemisphere and spread northwards, and that this is particularly true of primitive families.

Further, he postulates a more continuous land mass in the south contemporaneous with the Palaeozoic of the northern (Holarctic) land mass and that the divergences of the basic, generalized familial groups had been accomplished on this southern land mass certainly by the Mid-Mesozoic. Du Rietz discussed at length the problems here being considered. It is somewhat difficult to determine his standpoint on the major problem.

He more or less rejects long distance dispersal of disseminules and the hypothesis of continental drift but accepts the need for "epeirogenetic transtropical highland bridges older than the mountain-chains of the Alpine Orogen. Such highland bridges may have existed not only in Africa, but also bordering the transtropical Alpine geosynclines (i.e. the Andean and the Malaysian geosynclines), partly passing over present deep sea bottom."

Since we do not know when, where, or from what the angiosperms were evolved, their early differentiation into families must largely remain a matter for speculation. Even more than phylogeny must the centre or centres of origin be hypothetical. Hypotheses are essential but they must not become dogmas. Two matters are worth bearing in mind. If there has been considerable drifting of continents and large wanderings of the poles the question of northern or southern origin of the families of angiosperms becomes largely meaningless as at present stated.

Secondly, assuming that the continental masses and the positions of the poles have not greatly changed since the origin of the angiosperms, apart from the accepted regressions and transgressions of the sea proved by geological researches there would appear to be good reasons for migrations to have occurred in both north and south directions. Certainly one has to postulate the diversified evolution of some taxa in the temperate regions of the Northern Hemisphere and of others in the Southern Hemisphere independently.

Continental Drift

The Pacific, Indian, and Atlantic Oceans are great expanses of water, separating continental land masses, with floras and faunas having some families, genera, and, more rarely, species in common. To account for common biological features it has frequently been postulated that there were land connections across which disseminules were more or less gradually and continuously dispersed. On the geomorphological side there was the possibility of former connecting land having sunk beneath the oceans or of formerly joined land masses having drifted apart.

It is first essential to be clear concerning the problem involved. Geological evidence is conclusive that there has been throughout the geological periods regressions and transgressions of the sea relative to dry land. All marine sedimentary rocks now forming part of land masses were laid down beneath seas and, whatever the depth of these, they formed barriers to dispersal of land plants as effective as deep oceans relative only to their extent. Conversely, none can dispute that former land linked many islands to continents, as Great Britain to Europe, or peninsula to peninsula, as Asia Minor to Greece.

Even if the Mediterranean Sea be accepted as the relict of a very ancient and more extensive Tethys Sea its outlines have changed enormously through the ages. The problems we have to consider here are both much greater and more controversial. Have the ocean basins, beyond the continental shelf always been very much as they are now or have they previously been land? If the latter, has their formation been due to submergence of land or to drifting of continents? If either submergence or drifting has occurred when did it happen? Biologists who have demanded continuous land surfaces to account for existing ranges of plants and animals have between them, in imagination, pretty well filled up all the oceans with land. On the contrary, many geologists and geomorphologists have accepted the view of the permanence of the great ocean basins so strongly put forward by J. D. Dana and summarized in his own words as "The continents have always been the more elevated land of the crust, and the basins always basins."

This view has often been stated in geological text-books and was widely accepted though challenged by scientists from time to time, and especially, as far as Gondwanaland was concerned, by Suess and others. Gondwanaland is the name given to a supposed great southern continent, wide enough to include much of South America, South Africa, India, part of Australia, Antarctica, and the intermediate areas now oceanic. It was thought to have persisted through the Palaeozoic era to Upper Cretaceous times.

The geological, palaeontological, and biogeographical evidence for some kind of former linkage of existing and now separated lands in the Southern Hemisphere is considerable but objections to the foundering of huge areas of land to provide the oceans or parts of the oceans now separating the Gondwanaland fragments have been raised by geophysicists and others.

More recently there has come to the fore the idea of drifting continents. This is now largely associated with the name of Alfred Wegener, though it appears it was, in one form or another, put forward by other geomorphologists before Wegener. Briefly, it is postulated that in Palaeozoic times there existed one great original continent, Pangaea, surrounded by a primeval Pacific Ocean. Then, during the Mesozoic and Cainozoic eras this one original continent broke up, and by the drifting of its fragments oceans gradually opened up between them.

Wegener adopted the old idea that the continents are composed mainly of the lighter silicates, having a mean density near that of granite, and float on a layer of heavier, viscous silicates. He postulated a general drift of the continental blocks away from the poles and towards the west. The details of Wegener's scheme have been modified in various ways by more recent workers but the general principle of continental drift is widely accepted and yet, one must add, often opposed.

Many biogeographers are inclined to accept continental drift as solving all their problems, which it certainly does not do, and the main criticisms have come from palaeobotanists and geophysicists, the latter being concerned with the source of the energy needed to shift continents. The whole subject has been complicated by linking continental drift on to hypotheses concerning "wanderings of the poles" and variations in the inclination of the earth's axis. Koppen and Wegener traced polar displacements, with tabulated records of latitude and longitude, from the Devonian to the present positions of the poles.

The majority of palaeobotanists, from a study of the records of fossil plants, especially those around the present North Pole, have been emphatically against polar migrations. Most recently there have been important researches on the permanent magnetization of the rocks and deductions therefrom. Evidence has been produced that the direction of magnetization of rocks (particularly of iron oxide minerals) perpetuates that of the earth's field at the time of their formation.

Hence, by examining rocks of known age it is possible to discover any variations that have taken place in the direction of the earth's field and the conclusion has been reached that the geomagnetic field has undergone repeated reversals in geological time. It has been assumed from these accepted displacements of the magnetic pole that there has been both translation in a meridional direction and rotation of land masses. Thus, Britain is said to have moved a long way northwards in the last 150 million years from a position about 10° north of the equator (roughly the latitude of Southern India) and North America has done the same.

England has also rotated through about 35° relative to the direction of present magnetic north and this could probably be interpreted as an increase of the distance between North America and Britain. Other, and sometimes decidedly different, estimates have also been made. There is apparently a postulate that the magnetic and geographical poles have always been associated much as they are now.

Another line of recent research which may be expected to throw light on the history of the oceans is the study by modern methods of the ocean floors. These are covered with oozes and the depth of these is determined by echoes from high explosives detonated at various depths. Echoes, it is accepted, are reflected both from the surface of the ooze and from that of the solid rock on which it rests. From the records it is possible to estimate the thickness of the ooze.

A further calculation based on the rate of sedimentation then allows an estimate to be made of the minimum age of a given portion of the ocean. On the whole, the recent results obtained by the Swedish *Albatross* expedition are against the theory of continental drift as applied to the Atlantic and as put forward by Wegener, since the estimates are for a time span of 300 to 400 million years, possibly still more.

Very recently actual borings into the sea floor, in fairly deep water, have been made off the Californian coast and it has been suggested that there is no known theoretical reason why borings to considerable depths should not be made into the crust at very considerable oceanic depths. Such might settle many questions at present controversial.

The literature on the subjects outlined above is extensive. The following books and papers may be consulted: Wegener, Koppen*und* Wegener, Du Toit, Brooks, symposium on *"The Theory of Continental Drift"*, Runcorn, Chaney, Petterson, Mayr, Edwards. The theory of continental drift, if accepted, obviously solves some phytogeographical problems, even if it leaves many untouched and raises some new ones. It is, perhaps, right to take the floras of South America and Tropical Africa as the simplest test. Wegener fitted the Brazilian bulge into the Gulf of Guinea and postulated the separation of Africa and America as commencing in the Cretaceous. We do not know when or where or from what the Angiosperms arose but there were certainly many existing families of flowering plants in existence and widely ranging by Cretaceous, even Lower Cretaceous, times while gymnosperms had evolved long before.

Palaeobotanically the angiosperms and gymnosperms are crucial for the question of dispersal since their seeds are, with few exceptions, large and heavy compared with the spores of cryptogams. What then are the resemblances and differences found on comparing the spermatophytic floras of Africa and South America? There are about 300 species at most known in the natural or subspontaneous state to be common to the two areas.

Many of these are halophytes (some 30 spp.) easily transported by tides and currents, or aquatic and marsh plants (about 100 spp.) often of wide range and frequently dispersed by birds, or pantropical species spread by man. More critical data for our purpose are to be found at the levels of families and genera.

Good lists generic connections across the South Atlantic, excluding pan-tropical genera, as follows:

America, Africa and/or Madagascar, etc.: 27 genera.

America and continental Africa only: 64 genera.

America and Madagascar only: 4 genera.

Some of these genera are wrongly included, though, on the other hand, some can be added. The total is a fairly large one but needs very much more detailed analysis than it has received. At the family level, connections between America and Africa excluding Madagascar are shown by *Bromeliaceae, Caricaceae, Humiriaceae, Loasaceae, Mayaceae, Rapataceae,* and *Vochysiaceae,* and those between America and Africa including the Madagascan region are shown by *Canellaceae, Hydnoraceae, Strelitziaceae, Turneraceae,* and *Velloziaceae.*

While it appears that the lists of genera and families of angiosperms common to South America and Africa can be given as evidence of a former land connection, and, indeed, of continental drift, some of the ranges can be otherwise explained.

Thus, the *Bromeliaceae* are American except for *Pitcairnia feliciana* from French Guinea and Chevalier accepts the view that "violent aerial currents" carried the light seeds of a species of *Pitcairnia* from the Caribbean islands, or from more eastern islands that have now disappeared, to West Africa and that isolation then led to differentiation from all American known species. *Rhipsalis (Cactaceae)* may have been dispersed by birds or by man, at least, there has been much controversy regarding the history of the present range of this genus.

The possibility that some of the South American-African discontinuities are due to independent migration southwards from some common northern source where the genus or family is now extinct must be kept in mind. It is also important to remember that many genera (and even some tribes and families) are not common to Africa and America. Whether these evolved after separation of Africa and America, if the continents were formerly joined, or if they have died out in one or the other we do not know.

Oceanic Islands

Islands have a fascination for the biogeographer. Their boundaries are definite, the land area is often not too great for a relatively detailed survey, the problems involved are often clear-cut and peculiar. There are, of course, many different kinds of islands: off-shore islands, continental, oceanic, solitary, archipelagos, volcanic, coral, and so on, and they range in size from mere rocks to continents.

As showing isolation from continental land masses, oceanic islands allow the investigation of certain phytogeographical problems under almost experimental conditions of abstraction. In particular, those of volcanic origin, with no indication of any former attachment to continental land have unique conditions for the study of the origin and development of the flora.

They usually have a natural flora poor in species, relatively rich in endemics, and showing taxonomic affinities in one or more directions. Unfortunately, the flora of many of the islands has been greatly modified by man and sometimes largely destroyed, an extreme example being the indigenous flora of St. Helena. The famous lecture by J. D. Hooker on "Insular Floras" summarized the floristic characters of a number of islands. He pointed out that they are rich in cryptogams, have many evergreen but few herbaceous plants and fewer or no indigenous annuals. Species are few in proportion to genera and genera in proportion to families, and the total number of species is small compared with continental areas of equal size and similar conditions.

Many more oceanic islands have been investigated, or much more fully investigated, botanically since Hooker's time and new developments both within the realm of biology and outside it have to be taken into consideration. Nevertheless, several of the major problems remain much as they were in 1866. These oceanic volcanic islands have, or naturally had, a rich vegetation of a limited number of species.

It is extremely unlikely that the ancestors of these species originated by any form of special creation in these islands and they must, therefore, have arrived from other areas, probably continental, either across land that has now disappeared or transoceanically. The efficiency of long distance dispersal has been a matter of controversy. No one disputes that disseminules (spores, seeds, etc.) can be scattered some distance from the parent plant, the distance being commonly a matter of yards to a few miles.

The evidence for long distance transport over oceans, extensive deserts, etc., is indirect or meagre, with one exception. It is generally agreed that ocean currents can transport some disseminules for long distances but these are those either of strand plants or of relatively few species that withstand immersion in sea water for a considerable time. Man, of course, is recognized as the most efficient of all transporting agents but we are here concerned with the floras that originated before the advent of man. The two natural agencies whose efficacy over very long distances is in dispute are wind and birds. There is a little direct evidence of wide dispersal by both but more is difficult to obtain. Modern research is badly needed. Spores and bacteria are certainly carried widely in the upper atmosphere and it is to be hoped that those engaged in aerobiological work will extend their methods and observations to seeds and other disseminules.

Cyclones may be important. Birds are said generally to travel on long distance migrations with empty alimentary systems and with clean feet and feathers. There is, however, an open field for combined botanicalornithological research here. Migrating birds are now ringed in large numbers. If they could always be carefully examined for attached fruits and seeds and if some such could be attached to them experimentally immediately previous to migration, and if the bodies of dead immigrants (at lighthouses, etc.) could be analysed externally and internally for plant parts, much might be learnt.

The question of land connections has been dealt with above and it need only be said now that problems of wide dispersal are also found over many continental areas where they are sometimes at least as puzzling as for oceanic islands.

There is much indirect evidence in favour of some transoceanic dispersal. The richness of many oceanic islands in cryptogams with their light spores, especially of bryophytes and pteridophytes, suggests wind dispersal has occurred for these plants. For seed plants, the poverty in taxa and the mixture of taxa suggest chance dispersal, as does also the absentees which might be expected had there been direct land connections. Sometimes the taxonomic affinities of the flora of an oceanic island, or island group, are correlated with general direction of the wind or with bird migration routes. Finally, we may note that the two hypotheses of dispersal over long distances and of land connections are not mutually antagonistic for both may have happened, one for this island, one for that, or both for the same island.

Given the establishment of a flora on an oceanic island there are the problems concerned with its further development *in situ*. Cytogeneticists and others engaged in population studies now, rightly, stress the pros and cons of isolation. In the evolution and maintenance of taxa (especially of species) isolation means reduced biotic competition, reduced swamping or extermination of mutations since there will be no flow of new immigrants, and absence of hybridization outside a very restricted population.

Compared with a large continental area the agents of natural selection will be different and, on the whole, less intensive. The climate, for example, is usually more equable than in a continental area, while predators, diseases, and pests are often less numerous. Thus evolution may be slower and old kinds or old characters are likely to survive. On the other hand, mutational characters suited to the conditions of an oceanic island, but less suited to those of a continent, will be selected.

5

Natural Vegetation and Ecosystem in Biogeography

NATURAL VEGETATION OF INDIA

Have you noticed different kinds of plants and vegetation when you travel to different states? Even around your house, you can notice various types of trees and bushes! Such is the diverse natural vegetation of India. In this chapter, we will cover some basics about the natural vegetation of India. We will also look at some interesting classifications and examples of the same.

What is Natural Vegetation

Natural vegetation refers to a plant community which has grown naturally without human aid. They have been left undisturbed by humans for a long time. We call this virgin vegetation. Thus, cultivated crops and fruits, orchards form part of vegetation but not natural vegetation. Now, we will look at some of the factors that impact the vegetation in our country.

The Climate of the Region

Temperature and humidity determine the character and extent of vegetation. The precipitation and soil also play a major role in determining the degree of vegetation. Therefore, various places in India have various vegetation patterns.

Photoperiod also affects the vegetation of a place. It is the variation in duration of sunlight at different places due to differences in latitude, altitude, season and duration of the day. Hence, depending on the photoperiod, you get different kinds of vegetation at different places. Now, we will look at the various types of vegetation.

Types of vegetation

We have the following major types of vegetation in our country:

Tropical Rain Forests

These forests are restricted to heavy rainfall areas of the Western Ghats and the island groups of Lakshadweep, Andaman and Nicobar, upper parts of Assam and Tamil Nadu coast. They are at their best in areas having more than 200 cm of rainfall with a short dry season. The trees reach great heights up to 60 meters or even above. Some of the commercially important trees of this forest are ebony, mahogany, rosewood, rubber and cinchona.

Tropical Deciduous Forests

These are the most widespread forests of India. They are the monsoon forests and spread over the region receiving rainfall between 200 cm and 70 cm. Trees of this forest-type shed their leaves for about six to eight weeks in dry summer.

These forests exist, therefore, mostly in the eastern part of the country – northeastern states, along with the foothills of the Himalayas, Jharkhand, West Orissa and Chhattisgarh, and on the eastern slopes of the Western Ghats. Teak is the most dominant species of this forest. Bamboos, sal, shisham, sandalwood, khair, Kusum, Arjun, mulberry are other commercially important species.

The Thorn Forests and Scrubs

In regions with less than 70 cm of rainfall, the natural vegetation of India consists of thorny trees and bushes. This type of vegetation is found in the north-western part of the country including semi-arid areas of Gujarat, Rajasthan, Madhya Pradesh, Chhattisgarh, Uttar Pradesh and Haryana. Acacias, palms, euphorbias and cacti are the main plant species. Trees are scattered and have long roots penetrating deep into the soil in order to get moisture.

Montane Forests

In mountainous areas, the decrease in temperature with increasing altitude leads to the corresponding change in natural vegetation of India. You can find the wet temperate type of forests between a height of 1000 and 2000 metres. Evergreen broad-leaf trees such as oaks and chestnuts predominate. Between 1500 and 3000 meters, you can find the temperate forests containing coniferous trees like pine, deodar, silver fir, spruce, and cedar.

Mangrove Forests

You can find the mangrove tidal forests in the areas of coasts influenced by tides. Mud and silt get accumulated on such coasts. Dense mangroves are the common varieties with roots of the plants submerged under water. You can find these in the deltas of the Ganga, the Mahanadi, the Krishna, the Godavari and the Kaveri.

Medicinal Plants in India

India is famous for its herbs and spices from ancient times. The World Conservation Union's Red list has named 352 medicinal plants of which 52 are critically threatened and 49 endangered. The commonly used plants in India are:

- Sarpagandha: We can use it to treat blood pressure. It is found only in India.
- Jamun: The juice from ripe fruit helps to prepare vinegar which is carminative and diuretic, and has digestive properties. The powder of the seed helps in controlling diabetes.
- Arjun: The fresh juice of leaves is a cure for an earache. It also regulates blood pressure.
- Babool: People use the leaves to cure eyesores. Its gum is used as a tonic.
- Neem: It has high antibiotic and antibacterial properties.
- Tulsi Plant: It helps to cure a cough and cold.
- Kachnar: This plant helps to cure asthma and ulcers. The buds and roots are good for digestive problems.

Natural Vegetation

Natural vegetation here refers to the natural forest, which in general defines a community of living trees and associated organisms, covering a considerable area, utilizing sunshine, air, water, and earthly materials to attain maturity and to reproduce itself; it is capable of furnishing humankind with indispensable products and services. In general, tropical forests play a vital role in nutrient storage and cycling on land. Nutrients are distributed not only through the trees, but also in the soils, with nutrient cycling playing a key role in the functioning of tropical forest ecosystems and enriching soils, especially surface soils. Any disturbance of forest cover can cause a significant loss of nutrients from the land. The forest types of the country, which in this case are evergreen and deciduous forest types, are influenced by local climate conditions. The simple difference between these two groups is that, in a deciduous forest almost all species of flora in the forest will shed their leaves in the long dry season months. In an evergreen forest there is a higher rainfall and species will fall and replace leaves all year and the forest remains green all year round.

The evergreen forest can be subdivided into four types: the tropical evergreen, the coniferous, the swamp and the beach forests.

The tropical evergreen forests occur along the wet belt of the country, where high annual amounts of rainfall of 1,500 mm and up prevail; they are affected by the monsoon. This forest ecotype is further divided into three categories: tropical rain forests, dry or semi-evergreen forests,and hill evergreen or lower Montana forests.

The tropical rain forests prevail in southeastern and peninsular regions where contact with the monsoon is direct; the precipitation is very high, 2,500 mm and up annually. The principal trees in the lower zone, up to 600 m altitude, are mostly Dipterocarps, while in the upper zone, 600-900 m altitude, oaks and chestnuts are common.

The dry or semi-evergreen forests are scattered over the country along the valley of low hill ranges of about 500 m elevation, or forming communities along streams and rivers. The annual precipitation is between 1,000-2,000 mm.

The principal trees of this forest ecotype are Anisoptera, Dipterocarpus, Hopea, Tetromeles and Lagerstroemia ssp.

The hill evergreen forests occupy the upper elevations from 1,000 m rising, all over the country with the larger percentage occurring in the northwestern highlands. This type of forest is known also as temperate evergreen forest or the lower Montana forest. The dominant tree species are oaks and chestnuts.

The coniferous forests occur in small pockets in the northwestern highlands and the Khorat Plateau (about 200-1,300 m elevation), where poor acid soil is found. The annual rainfall is about 1,000-1,500 mm. The dominant species are Pinus merkusii and Pinus kesiya.

The swamp forests occupy areas that are more or less subjected to occasional inundation , and are scattered in the wet regions of the country where the annual precipitation is high (in excess of 2,000 mm). This forest type can be further classified physiographically into two kinds: the mangrove swamp forest and the fresh water swamp.

The beach forests occur in areas along the beach, where sand dunes, rocky seashores and elevated seacoasts prevail. The dominant species are Casuarinas equisetifolia and Terminalia catappa

The deciduous forests occupy the dry belt of the country, where precipitation is low (under 1,000 mm annually) and the climate is more seasonal; the soil is sandy and lateritic. The vegetations of these zones are classified as deciduous formation. The tree species of this type shed their leaves during the dry season and tend to develop growth or annual rings. Deciduous forests can be subdivided into three main categories: the mixed deciduous, the dry dipterocarp, and the savanna forests.

The mixed deciduous forests occur between elevations of 50-600 m. The principal tree species are Tectona grandis, Lagerstroemia, Terminalia, Afzelia, Xylia, Peterocarpus and Dalbergia spp., most of which are high-value commercial species.

The dry dipterocarp forests occupy areas on the undulating peneplain and ridges. The dominant tree species are Shorea obtuse, Shorea siamensis, Dipterocarpus tubercultus and Dipterocarpus obtusifolius.

The savanna forests originate from burning, which then forms a deciduous type. It is found more frequently in the northeastern region, where the precipitation is relatively low (from 50-500 mm annually). The savanna is, in essence, a grassland where trees of medium height grow sparsely, forming a very open stand interspersed with thorny shrubs and Bambusa arundinacea.

ROLE OF VEGETATION IN THE PROCESSES OF PEDOGENESIS

The role of vegetation in the processes of pedogenesis has been studied under conditions where the distribution of the phases of plant development in space corresponds to their sequence in time and thus provides an unequivocal chronological succession over a prolonged period with respect alike to soils and organisms. For sand dunes it has been shown that the soil development is dependent upon a succession of species that incorporate organic material beneath the surface as well as providing deposition upon it and augment water retention and stability so that less and less specialized types can effect colonization ultimately ousting the pioneer specialists. The original inhospitable soil conditions with an open community of perennial and annual species, characterized by features that enable them to endure the rigorous conditions, is succeeded by conditions favourable to an increasing number of species, far more diverse in their biological equipment, that ultimately constitute a closed community and this in turn may finally give place to scrub and woodland occupying soil that is now favourable to a great diversity of plants but where in fact the number of species has again diminished owing to the dominance of trees and shrubs. The initial edaphic specialization has thus, in the course of perhaps a century, given place to a biotic specialization that in its own way may be almost equally severe. The studies of R. L. Crocker and his associates on the recessional moraines deal with a comparable sequence from an open community of pioneers that in the course of some 120 years has developed to spruce forest and, as in the dune succession, there is an increasing organic content and transition from an initially alkaline soil to one of appreciable acidity with an augmenting gradient in the soil profile.

The recognition of the major role in water retention by the soil played by the organic material gives added significance to its vertical distribution and it thus came to be realized that, in the naturally stratified soil the surface layer might be of sufficient thickness and its organic content so high that it constituted a sponge which could starve the lower layers of water except perhaps in the heaviest rainfall. Thus is indicated one of the ways in which during the course of years a tall deeply rooted layer of dominant species continually adding its quota to the superficial organic accumulations can gradually contribute to its own destruction and an acidophile shallow-rooted community replaces the erstwhile dominants. Each species has its own complex of conditions in which it can best develop. If we grow any one in conditions that vary with respect to one factor, such for instance as soil reaction, we find there is a range over which the plants exhibit maximum growth on either side of which increasing acidity or increasing alkalinity is accompanied by diminishing vigour. In the absence of competition the range of toleration is often wide but in the presence of other species this may become very restricted. This fact emphasizes the fundamental principle of the interaction of habitat factors.

For whether it be soil reaction or any other there is usually no absolute optimum but a relativity that is the more complex because any single one may operate in so many different ways. Soil acidity, for example, may be beneficial as enabling certain nutrient ions to be readily available but it may also be directly harmful by reason of toxicity of the hydrogen ions themselves, or indirectly through excess of ions of alumina or manganese in the soil solution, or again it may adversely affect beneficial soil organisms such as the nitrogen fixing bacteria and encourage harmful ones such as *Plasmodiophora brassicae.* Above all, adverse or beneficial factors cannot be considered in isolation since plants grow where they must and not where they will so that what, in the laboratory experiment, may seem harmful appears in the field as a benefit because the species concerned is more tolerant of this condition than its normal associates. For instance *Viscaria alpina* can apparently tolerate a copper content in the soil toxic to most species. Again what favours vegetative growth is often detrimental to seed production and which of these is the more important may vary from time to time in one and the same plant community. Experiments have repeatedly shown that the optimum conditions with respect to various factors alter with the stage of development of the individual and also its susceptibility.

"The field for the problem and the laboratory for the solution" is only very partially true for ecological studies, for laboratory findings must be transmuted into the far more complex context of so many other variables that experience alone can guide as to what may be applicable and to what degree. But field studies, both observational and experimental, should serve as the means for testing hypotheses based upon what the plant physiologist has ascertained. Ecology is essentially applied plant physiology with the competition factor as an important modifying influence in a physical environment that represents the interaction of climatic, edaphic, and biotic factors that are themselves abstractions from a sequence of continual change.

The emphasis on physiognomy that has formed the basis for some systems of classification of plant communities can be regarded as an attempt to utilize the plants themselves as integrators of the physical conditions and the concept of the so-called indicator species is but another aspect of the same theme.

When extreme conditions are under consideration the correlation of physiognomy with habitat conditions is sometimes surprisingly high as is well exhibited, for example, on some of the sandy and areas in South-West Australia, where communities are encountered consisting of species of the most diverse genera and families yet resembling one another so closely in their general physiognomy as to be difficult to distinguish except when in flower or fruit. In less differentiated conditions, however, as for instance in the temperate woodland, the same stratum, where there is relative uniformity of environment, often presents a great range of morphological diversity that suggests either that physiognomy is an unsatisfactory guide or that our knowledge must be greatly increased by experiments, in the field of environmental morphogenesis, before we are in a position to assess what morphological characteristics are significant and what are irrelevant.

Stratification and Seasonal Development of Aerial Shoots

The stratification and seasonal development of aerial shoots, to which attention was drawn by Kerner Von Marilau nearly a century ago, and of the subterranean organs, which the late Dr. Woodhead was one of the first to investigate, both affect the competitive efficiency of the species whilst the periodicity of the important phases of the life history and their modifications by the environment are no less significant though too little investigated. These latter, for economic reasons, are better known with respect to horticultural plants. The gardener is familiar with the fact that most plants are best moved in the dormant state, yet most species of *Helleborus* thrive best if transplanted when in full flower, a difference probably related to the phases of root development. Or again, careful investigations of bulbous species have shown how temperature fluctuations can affect differently diverse cultivars of the same species apparently by reason of their individual rhythms in the production of flower initials. What is true of cultivated plants is probably equally true of wild species and emphasizes for us that the understanding of the communal life of plants is dependent upon a knowledge of the idiosyncrasies of its chief constituents.

The structure and chemical characteristics of the soil as they affected plant life gained no small impetus from the work of Lawes and Gilbert, initiated in the early forties of last century, but the classical work of E. J. Russell on *Soil Conditions and Plant Growth,* which first appeared in 1912 and which passed through eight editions and has been translated into various languages, probably did more than any other single publication to bring before the minds of botanists the complexity as well as the importance of edaphic conditions upon vegetation. The soils that the agriculturist had studied were, however, to a very considerable degree physically homogenized by the processes of cultivation and chemically altered by their manurial treatment. It was not until ecologists began to pay attention to the organization that is exhibited by natural soils that the degree of applicability of the findings of the agriculturists could begin to be assessed. One of the earliest recognitions of the structure of natural soils and its relation to the vegetation which they bear was the study by Gesser and Siegrist of the profiles in the soils of the Aare communities in Switzerland. In this country the present writer called attention to the striking vertical gradients with respect to organic content, water content, soil reaction, and other features exhibited by woodland and sand-dune soils which provide a gradient of conditions for the root system.

These vertical changes not only contribute to the establishment and maintenance of the complementary communities of species but, as soils derived from a calcareous substratum strikingly show, can provide one and the same root system with a diversity of conditions favourable for the easy acquisition of the whole range of nutrient requirement from an acid surface layer from which the ions of iron and manganese may be readily obtained to an alkaline subsoil from which molybdenum is readily available.

ECOSYSTEM DIVERSITY

Analogous to species diversity, the number of ecosystems and pattern of their distribution can be used as a measure of ecosystem diversity. While we know of no examples where fishing activities eliminated an ecosystem, there are several examples where fishing activities have resulted in major reduction in the regional distribution of ecosystem types over large areas.

Mariculture—the farming of economically valuable sea life—is a fishing activity that has significantly altered coastal and estuarine habitats in many parts of the world. Along the coasts of Ecuador and Thailand, for example, fish farms have replaced mangrove habitats over fairly extensive areas. In order to build aquaculture facilities to raise shrimp and fish, mangroves are dug out and replaced with ponds, eliminating essential nursery habitat for many fishes. While mangrove ecosystems have not disappeared on a global scale, on a regional level there have been significant reductions in the total area of mangroves; a form of ecosystem depletion.

There are other examples of ecosystem diversity being affected by fishing activities that destroy habitat upon which complex communities of marine organisms rely. Overfishing of herbivorous fishes on coral reef complexes in the Caribbean, as in the example above, has directly resulted in coral reef die-offs. The use of dynamite and cyanide in Southeast Asia to catch reef fish for local consumption and the aquarium trade has also killed off significant expanses of coral reefs. Trawling, where heavy nets are dragged along the ocean floor, can also damage seagrass or rocky habitats, physically dislocating or crushing fish and shellfish, undermining structural needs, and disrupting food availability for creatures such as shellfish and groundfish.

The dance of life operates in diverse, strange, and mysterious ways. Understanding the biological processes influencing the functional relationships of marine organisms, species, and whole communities has practical implications for understanding the consequence of human actions. As a species reliant on the biological productivity of oceans, in order to optimize the benefits humans can gain from this vessel of life, we need to know how to minimize the negative consequences of our actions for other living things, and for future generations. Even with better understanding of the human factors influencing marine biological diversity, fisheries management is inevitably a matter of politics, not science. Management will not succeed in preserving future options unless it is both scientifically informed and ethically responsible.

Marine Biodiversity Important

The seas provide a unique set of goods and services to society, including moderation of climate, processing of waste and toxicants, provision of vital food, medicines and employment for significant numbers of people. Our coasts provide space to live and directly and indirectly create wealth, including millions of jobs in industries such as fishing, aquaculture and tourism..

Looking at ecosystems in terms of the goods and services they provide allows us to realise their full value and our dependence on those systems in the broadest sense. Exploitation of the environment for one purpose can alter the environment's ability to provide other goods and services, so this knowledge is also a way of understanding what we stand to gain and lose by exploitation of certain aspects of the environment. The main goods and services provided by marine ecosystems are:

Resilience and resistance

Coastal and marine ecosystems are affected by environmental disturbance at a variety of spatio-temporal scales. The organisms inhabiting these systems are adapted to such disturbance, either by being tolerant of these conditions or by playing a role in one or more of the successional stages that follow during ecosystem recovery.

If all species in the system were tolerant to a particular perturbation, very little would change at the ecosystem level, and we could call the system resistant to this disturbance. However, often a disturbance, such as a temporary very low oxygen level, affects a substantial proportion of the organisms dramatically, either causing them to die, or forcing them to rapidly migrate to more favorable parts of the environment. Such a catastrophic disturbance could locally defaunate a certain volume in the pelagic or a certain area of hard or soft substrate.

Such destruction at a local scale does not mean the end of local functioning; Usually organisms are available at a larger spatial scale that can re-colonize the affected area, according to their particular tolerances and abilities to favorably affect their local environment. The term resilience has been used in different ways, first of all for the rate of recovery to the previous state and secondly for the system's ability to re-organize itself. Both resistance and resilience cause an ecosystem to remain relatively unchanged when confronted by a disturbance, but in the case of resistance no internal re-organization and successional change is needed. In contrast, resilience implies that the system is internally re-organizing, perhaps through a mozaic of patches that are at different stages of re-assembly.

When considering the potential effect of a certain type of disturbance it is thus useful to ask two questions: (1) Will the species of this system be able to tolerate it (implying resistance), and if not, (2) Is recovery possible through a successional trajectory, back to the same, or at least a desirable, ecosystem state (implying resilience)?

It should be clear that the system will not be sufficiently resistant when (even gradual) uni-directional change acts faster than the organisms' ability to adapt their tolerances. If uni-directional gradual change is this fast, the system will not be sufficiently resilient either, as full recovery through succession will then not be possible. Recovery from sudden and local disturbance is usually possible through re-colonization, but the rate of recovery will depend tremendously on the spatial extent of disturbance. For example, recovery from anoxia could take 5 to 8 months at the scale of square meters, but could take 5 to 8 years at the scale of a whole bay.

Resilience has been defined in different ways: it can be a measure for the speed at which an ecosystem returns to its former state following a (minor) disturbance. The idea is that a system with a short return time is more resilient than one with a long return time. Such resilience measured as (1/the return time to a stable equilibrium) has also been called *engineering resilience*. It has however a long history of use among ecologists. It is also used in a way that more closely resembles the definition of resistance.

Biodiversity allows ecosystems to adapt to changing conditions. Humans, however, have acted to increase the rate of change and consequently, it will be a great challenge for the marine environment to adapt rapidly enough in the future. These changes have been induced through pollution, fishing, sediment deposition and alteration of the global climate. Without genetic diversity, natural selection cannot occur and natural selection is limited, then adaptation is impossible. It is evident that the preservation of biodiversity and, more specifically, genetic diversity is of paramount importance for successful adaptation to our rapidly changing environments.

Resilience through re-colonization

To understand resilience of ecosystems it is essential to understand what drives succession within these ecosystems. Succession determines how, and how fast, communities return back to their original state, or perhaps enter a new state. many aspects of succession can be understood in terms of trade-offs between the ability to be either a good early (re-)colonizer, or a good competitor (r-species versus a K-species). Succession involves a gradual replacement of species that differ in these traits and that differ in the degree they tolerate, facilitate or inhibit certain environmental conditions and other species.

We could thus also call a system resilient when it is organized in such a way that succession leads to a recovery of the original state.

Resilience and Nutrient Inputs

DeAngelis *et al.* 1989 showed in their analysis of a food chain model that resilience, measured as (1/return time), increased smoothly with nutrient enrichment. The idea is that the system can more quickly return to its original state when the nutrient input is high. However, this result depends on the exact shape of the functional response, the way predators consume their prey as a function of prey density. DeAngelis *et al.* had used a highly stabilizing Type III (a sigmoid-shaped) functional response.

Such a functional response is realistic for learning predators and those that switch between different prey types. Vos *et al.* 2005 found that resilience (1/return time) would first increase, but then decrease again under nutrient enrichment, when a Type II functional response was used in the model. Many species of consumers throughout the animal kingdom consumer their resources with such a functional response, where intake rate first increases, and then gradually levels off with resource density. Food chains with such consumers would be much less resilient under a high pressure of nutrient enrichment.

Resistance to Changes in Abiotic and Biotic Factors

Community composition and ecosystem function may change very little under environmental change when the organisms can acclimate to such change or tolerate it for some time (when the change is only temporary). However, all organisms have bounds to what they can temporarily or permanently tolerate, and when change exceeds some of these limits, the community compostion and ecosystem functioning is likely to change.

It is unlikely that communities can be resistant to continuous gradual change, such as global warming. Acclimation and phenotypic plasticity do not suffice to maintain the system as it is. Genetic adaptation could allow community members to track such abiotic environmental change, but it is more likely that the area where the community is functioning will be invaded by species that function well at higher temperatures.

The original species will thus have to deal with new competitors and predators, in addition to the changed abiotic factor. To some extent the original community can track the preferred temperature range, by moving spatially to greater depths or to alternative gepgraphic areas. But these new areas are likely to differe in other ecological aspects such as water pressure, light climate and perhaps speeds of water flow etc.

Adaptation and the Consequences of Mortality

External disturbance interacts with internal mechanisms that shape community structure. To understand how an increased mortality of top-predators will affect the entire food chain, it is essential to understand how processes of mutual adaptation within food chains already give shape to existing patterns such as trophic structure (how biomass in ecosystems is partitioned between trophic levels (such as algae, herbivores, carnivores and top-predators)... Abundances at different trophic levels (such as algae, herbivores, carnivores and top-predators) and their responses to increased mortality (as under environmental change) depend critically on different mechanisms of adaptation within food chains and on the importance of density dependence at each of these trophic levels.

However, different types of adaptation to living in a food chain context (balancing the need to acquire resources with the need to avoid predation) can often have very similar consequences. For example, micro-evolution or behaviour, species replacement and induced defenses at a middle trophic level may all have similar effects on trophic level abundances in disturbed food chains.

Adaptation Assisted by Man

Protecting sources, not sinks when creating Marine Protected Areas. Protecting sources of populations at all stages of succession, to preserve 'ecological memory' to the fullest possible extent.

This includes protecting not only 'high quality' habitats that harbour healthy mature communities, but also 'low quality' and disturbed habitats that are required for those species that contribute to early recovery of perturbed areas.

Disturbance Prevention

Living marine flora and fauna can play a valuable role in the defence of coastal regions *i.e.* disturbance prevention. Marine ecosystems and the presence of organisms in the front line of sea defence can dampen and prevent the impact of tidal surges, storms and floods providing a 'buffering' effect that protects humans from the effects of these destructive perturbations. This disturbance alleviaion service is provided mainly by a diverse range of species which bind and stabilise sediments and create matural sea grass defences, for example salt marshes, mangrove forests and sea grass beds.

Sediments cover most of the seabed and hence most of the earth. Recycling of carbon and nutrients within this habitat (both subtidally and intertidally) is critical both at small and large scales. The availability of essential nutrients, such as nitrogen and phosphorus, and metals is essential for life. Processes that aid nutrient cycling are crucial to ecosystem functioning, as this increases the availability of nutrients and thus maintains productivity of the system. For example, in the marine benthic environment, bioturbation by marine worms, mainly through burrowing in the sediment, moves nutrients from deep sediment layers to the surface and vice versa. Nutrient cycling is also maintained through processes such as ingestion and excretion of materials by organisms *e.g.* fish mineralise nitrogen and phosphorus through excretion.

Gas and Climate Regulation

Marine ecosystems are an important regulator of global climate. Biogeochemical processes such as regulation of the CO2/O2 (carbon dioxide/oxygen) balance, maintenance of the ozone (O3) layer and sulphur oxides (SOx) are necessary to maintain a healthy planet and a healthy human population through the provision of breathable air. The biogeochemical cycling of gases is greatly controlled by the living biota existing on earth of which the marine realm is extremely important. For example, marine plants and animals aid in controlling carbon dioxide in the ocean, as phytoplankton remove it from the surface waters while releasing oxygen. When phytoplankton die, they sink and add to the supersaturation of carbon dioxide in the deep sea. This results in a vertical gradient of CO2 in the ocean, which has been termed the ‘Biological Pump.’ Greenhouse gas regulation is vital in regulating the climate of our planet. The seabed has a significant role in this process through its ability to sequester CO2. Gases such as CO2 in the atmosphere traps heat from the sun, heating the planet. This process occurs naturally and has kept the Earth's temperature about 60 degrees Fahrenheit warmer than it would otherwise be. Excessive amounts of gases such as atmospheric CO2, however, can have a significant contribution to global warming and is thus a factor in regulating climate..

Bioremediation of Waste

A significant amount of human waste settles on the seafloor, through wash off from land and through transport from rivers and estuaries. Waste settling on the seabed is stored, assimilated, diluted and recycled through chemical re-composition, these bioremediation processes which de-toxify and purify waste and are of critical importance to the marine environment. Through either direct or indirect activity, marine living organisms store, bury and transform many waste materials through assimilation and chemical de and re-composition. For example, the bioturbation activity (reworking and mixing of sediments) of mega-and macrofaunal organisms within the seabed can bury, sequester and process waste material through assimilation and/or chemical alteration. Marine organisms such as the polychaete worm, Nereis succinea, takes heavy metals through feeding on sediments.

These detoxification and purification process are of critical importance to the health of the marine environment.

Biologically Mediated Habitat

Many organisms provide structured space or living habitat through their normal growth, for example, reef forming invertebrates, meadow forming sea grass beds and marine algae forests. These 'natural' marine habitats can provide an essential breeding and nursery space for plants and animals, which can be particularly important for the continued recruitment of commercial and/or subsistence species. Such a biologically mediated habitat can provide a refuge for plants and animals including surfaces for feeding and hiding places from predators. Living habitat plays a critical role in species interactions and regulation of population dynamics, and is a pre-requisite for the provision of many goods and services.

One of the most tangible services provided by the marine environment is the provision of Food for human consumption. Plants and animals derived directly from marine biodiversity provide a significant part of the human diet. Fisheries in particular, and the accompanying employment, provide a significant example of the importance of this function.

However, those species that are harvested commercially tend to be very heavily exploited, with stocks of many traditional favourites such as North Sea cod facing the threat of collapse. Seaweeds such as giant kelp, nori and agarweed are also very important commercially, historically being extremely important in East Asia.

Conserving biodiversity of these groups will allow the use of under utilised resources in the future. A diverse ocean could potentially help to alleviate current and future commercial fishing pressures, provided these resources are managed responsibly.

Ornamental Resources

The oceans are a source of natural raw materials such as medicines, feed for livestock, polysaccharides and building materials. The potential for acquiring future raw materials from the marine environment is enormous.

Natural medicines continue to be discovered through the wealth of diversity on the planet. Although most medicines originate from sessile land plants, the ocean hosts many sessile animals that defend themselves through chemical means. The oceans host a high biochemical diversify resulting from the high phyletic diversity in marine ecosystems, suggesting there may be further potential to extract chemicals for pharmaceuticals from these organisms. An example includes the extract (arabinosides), collected from the sponge Tethya crypta and used in the treatment of herpes.

Red, brown and green algae provide a source of polysaccharides for a variety of human uses. Seaweeds are important in agriculture as feed for livestock and as compost for farmland. Chiton from shrimp and crab shells is used in agriculture as well as in human food supplements. An additional benefit of using these resources is that less of the animal is wasted from the fishery alone.

Aggregates extracted from the marine environment are used for building materials. Sand, gravel and crushed rock are used in the construction industry for housing and road building. Their removal has a physical impact on the seabed and habitat type through removal of material and resettlement of fine particles. Extraction must be carried out in a sustainable manner, as a healthy habitat is a prerequisite for the provision of goods and services from the marine environment. Marine biodiversity provides the basis for a wide range of leisure and recreational activities including: (sea) bird watching, rock pooling, beachcombing, sport fishing, recreational diving, and whale-watching. The provision of leisure and recreation results in significant employment opportunities.

Cultural Values

Cultural heritage and identity are intrinsically linked to the provision of food and employment is the support of cultural and spiritual traditions associated with fishing communities.

There is benefit associated with marine biodiversity for example for religion, folk lore, painting, cultural and spiritual traditions. Human communities living by and off the sea often attach special importance to marine ecosystems that have played a founding or significant role in the economic or cultural definition of the community. This identification may be associated with a strong economic interest in the extraction of the site but as economic significance decreases the community may attach increased symbolic values to the preservation of the site. For example a mussel bed may long have lost its economic significance while the symbolic importance may be high. This valuation should be distinguished from the economic importance of revitalised and commercialised cultural heritage which is included under the heading Leisure and recreation.

In Europe some of our most beautiful natural amenities are clean marine ecosystems, such as coasts, seas and estuaries, which enhance our landscapes and form an integral part of our cultural and natural heritage.

FUNDAMENTALS OF BIOGEOGRAPHY AND ECOSYSTEMS

Biogeography and ecological systems

Biogeography is the study of the geographical patterns of plant and animal species. To understand the distribution of plant and animal species on Earth, a fundamental knowledge of ecology and ecosystem dynamics is required.

Ecology is the study of the interactions among organisms. An *ecosystem* is a functioning entity of all the organisms in a biological system generally in equilibrium with the inputs and outputs of energy and materials in a particular environment. It is the basic ecological unit of study. There are two kinds of ecosystems, aquatic and terrestrial. An ecosystem is comprised of habitats, biological communities, and ecotones.

A biome is often referred to as a global-scale community of plants and animals and is the largest subdivision of the biosphere. A biome may contain many different kinds of smaller ecosystems. Biomes are typically distinguished on the basis of the characteristics of their vegetation because it makes up the largest portion of biomass. Biomes are subdivided by formation class, vegetation units of a dominant species.

A habitat is the natural environment in which an organism lives. Most African elephants live on savannas and in dry woodlands. Bass prefer a habitat of warm, calm, clear water and are usually found in slow-moving streams, ponds, lakes, and reservoirs. Habitats can be identified at different spatial scales. Macrohabitats are delineated by climate and subdivided on the basis of their vegetation. Microhabitats are smaller in size, such as the habitat along a stream channel or a layer within the canopy of a rain forest. Each species has specific habitat parameters (temperature, moisture, and nutrient availability).

ECOLOGICAL BIOGEOGRAPHY

We've seen how energy and matter move through ecosystems. But if we want to fully understand ecosystems, we'll also need to look at ecological biogeography, which examines the distribution patterns of plants and animals from the viewpoint of their physiological needs. That is, we must examine how the individual organisms of an ecosystem interact with their environment. From fungi digesting organic matter on a forest floor to ospreys fishing in a coastal estuary, each organism has a range of environmental conditions that limits its survival as well as a set of characteristic adaptations that it exploits to obtain the energy it needs to live.

Let's start by looking at the relationship between organisms and their physical environment. How living conditions can change across the Canadian boreal forest such that different regions support different ecosystems. In this way, we can distinguish six distinct habitats across the Canadian boreal forest: upland, bog, bottomland, ridge, cliff, and active sand dune.

We use the term ecological niche to describe the functional role played by an organism as well as the physical space it inhabits. If the habitat is the individual's "address," then the niche is its "profession," including how and where it obtains its energy and how it influences other species and the environment around it.

When describing the ecological niche, we talk about the organism's tolerances and responses to changes in moisture, temperature, soil chemistry, illumination, and other factors. Although many different species may occupy the same habitat, only a few of these species will ever share the same ecological niche, for, as we'll see shortly, evolution will tend to separate those that do. As we move from habitat to habitat, we find that each is the home of a group of organisms that occupy different but interrelated ecological niches. We can define a community as an assemblage of organisms that live in a particular habitat and interact with one another.

Although every organism must adjust to variations in the environment on its own, we find that similar habitats often contain similar communities. Biogeographers and ecologists recognize specific types of communities, called associations, in which typical organisms are likely to be found together. These associations are usually defined by species, as in the beech-birch-maple forest that is found from the Great Lakes region to New England in suitable habitats.

Water Need

Let's now turn to the environmental factors that help determine where organisms, as individuals and species, are found. The first of these is the availability of water. Plants and animals have adapted to cope with the abundance or scarcity of water in a variety of ways. Plants that are adapted to drought conditions are called xerophytes. ("Xerophyte" comes from the Greek roots xero-, meaning "dry," and phyton, meaning "plant.")

Some xerophytes have a thick layer of wax or waxlike material on leaves and stems, helping them to seal water inside. Others adapt to a desert environment by greatly reducing their leaf area or by bearing no leaves at all. Needlelike leaves, or spines in place of leaves, also conserve water. Plants in water-scarce environments are also better at obtaining and storing water. For example, their roots may extend deeply to reach soil moisture far from the surface until they reach ground water. Plants drawing from ground water are called phreatophytes. Other desert plants produce a widespread, but shallow, root system, so they can absorb water from short desert downpours that saturate only the uppermost soil layer. Leaves and stems of desert plants known as succulents are often thickened by a spongy tissue that stores water. The common prickly pear cactus is an example.

Many small desert plants have a very short life cycle—germinating from seed, leafing out, bearing flowers, and producing seed in the few weeks immediately following a heavy rain shower. They survive the dry period as dormant seeds that require no moisture.

Certain climates, such as the wet-dry tropical climate 3 , have a yearly cycle with one season in which water is unavailable to plants because of lack of precipitation. In these climates, some species of trees, termed tropophytes, are deciduous, shedding their leaves at the onset of the dry season and growing new ones with the arrival of the wet season. The Mediterranean climate 7 also has a strong seasonal wet-dry alternation, with dry summers and wet winters. Plants in this climate often have hard, thick, leathery, evergreen leaves and are referred to as sclerophylls.

Xeric animals have evolved methods that are somewhat similar to those used by the plants. Many of the invertebrates stay dormant during the dry period. When rain falls, they emerge to take advantage of the new and short-lived vegetation that often results. Many species of birds only nest when the rains occur, the time of most abundant food for their offspring. The tiny brine shrimp of the Great Basin may wait many years in dormancy until normally dry lakebeds fill with water, an event that occurs perhaps three or four times a century. The shrimp then emerge and complete their life cycles before the lake evaporates. Other animals have evolved more unique adaptations, such as changing their body color to absorb or reflect solar energy, depending on their internal temperature.

Mammals are by nature poorly adapted to desert environments, but many survive through a variety of mechanisms that enable them to avoid water loss. Just as plants reduce transpiration to conserve water, many desert mammals do not sweat through skin glands. Instead they rely on other methods of cooling, such as avoiding the Sun and becoming active only at night. In this respect, they are joined by most of the rest of the desert fauna, which spend their days in cool burrows in the soil and their nights foraging for food.

Temperature

The temperature of the air and soil directly influences the rates of physiological processes in plant and animal tissues. In general, each plant species has an optimum temperature associated with each of its functions, such as photosynthesis, flowering, fruiting, or seed germination. There are limiting lower and upper temperatures for these individual functions as well and for the total survival of the plant itself.

Temperature can also act indirectly on plants and animals. Higher air temperatures reduce the relative humidity of the air, enhancing transpiration from plant leaves as well as increasing direct evaporation of soil water. In general, the colder the climate, the fewer the species capable of surviving. We only find a few plants and animals in the severely cold arctic and alpine environments of high latitudes and high altitudes. In plants, ice crystals can grow inside cells in freezing weather, disrupting cellular structures. Cold-tolerant plant species are able to expel excess water from cells to spaces between cells, where freezing does no damage.

Most animals can't regulate their temperature internally. These animals, including reptiles, invertebrates, fish, and amphibians, are cold-blooded animals—their body temperature passively follows the environment. With a few exceptions (notably fish and some social insects), these animals are active only during the warmer parts of the year. They survive the cold weather of the midlatitude zone winter by becoming dormant.

Some vertebrates enter a state called hibernation, in which their metabolic processes virtually stop and their body temperatures closely parallel those of the surroundings. Most hibernators seek out burrows, nests, or other environments where winter temperatures do not reach extremes or fluctuate rapidly. Soil burrows are particularly suited to hibernation because below the uppermost layers, soil temperatures don't vary a great deal.

Warm-blooded animals, like us, maintain tissues at a constant temperature by internal metabolism. This group includes the birds and mammals. Fur, hair, and feathers insulate the animals by trapping dead air spaces next to the skin surface. A thick layer of fat will also provide excellent insulation. Other adaptations are for cooling—for example, sweating or panting uses the high latent heat of vaporization of water to remove heat. The seal's flippers and bird's feet expose blood-circulating tissues to the cooler surroundings, promoting heat loss.

Other Climatic Factors

Light also helps determine local plant distribution patterns. Some plants are adapted to bright sunlight, whereas others require shade. The amount of light available to a plant will depend in large part on the plant's position. Tree crowns in the upper layer of a forest receive maximum light but correspondingly reduce the amount available to lower layers. In extreme cases, forest trees so effectively cut off light that the forest floor is almost free of shrubs and smaller plants.

In certain deciduous forests of midlatitudes, the period of early spring, before the trees are in leaf, is one of high light intensity at ground level, permitting the smaller plants to go through a rapid growth cycle. In summer these plants largely disappear as the tree leaf canopy is completed. Other low plants in the same habitat require shade and do not appear until the leaf canopy is well developed.

The light available for plant growth varies by latitude and season. As we saw earlier, the number of daylight hours in summer increases rapidly with higher latitude and reaches its maximum poleward of the Arctic and Antarctic Circles, where the Sun may be above the horizon for 24 hours. The rate of plant growth in the short frost-free summer is greatly accelerated by the prolonged daylight.

In midlatitudes, where many species are deciduous, the annual rhythm of increasing and decreasing periods of daylight determines the timing of budding, flowering, fruiting, and leaf shedding. Even on overcast days there is usually enough light for most plants to carry out photosynthesis at their maximum rates.

Light also influences animal behavior. The day–night cycle controls the activity patterns of many animals. Birds, for example, are generally active during the day, whereas small foraging mammals, such as weasels, skunks, and chipmunks, are more active at night. In midlatitudes, as autumn days grow shorter and shorter, squirrels and other rodents hoard food for the coming winter season. Later, increasing hours of daylight in the spring trigger such activities as mating and reproduction.

Wind is also an important environmental factor in the structure of vegetation in highly exposed positions. Wind causes excessive drying, desiccating the exposed side of the plant and killing its leaves and shoots. Trees of high-mountain summits are often distorted in shape, with trunks and branches bent to near-horizontal, facing away from the prevailing wind direction.

Taken separately or together, moisture, temperature, light, and wind can limit the distribution of plant and animal species. Biogeographers recognize that there is a critical level of climatic stress beyond which a species cannot survive. This means that we can mark out a bioclimatic frontier—a geographic boundary showing the limits of the potential distribution of a species.

Geomorphic Factors

Geomorphic, or landform, factors such as slope steepness, slope aspect (the orientation of a sloping ground surface with respect to geographic north), and relief (the difference in elevation of divides and adjacent valley bottoms) help differentiate habitats for ecosystems.

Slope steepness affects the rate at which precipitation drains from a surface, which indirectly influences plants and animals. On steep slopes, surface runoff is rapid, but on gentle slopes, more precipitation penetrates into the soil, providing a moister habitat. Steep slopes often have thin soil because they are more easily eroded, while soil on gentler slopes is thicker. Slope aspect controls plants' exposure to sunlight and prevailing winds. Slopes facing the Sun have a warmer, drier environment than slopes that face away from the Sun. In midlatitudes, these slope-aspect contrasts may be strong enough to produce quite different biotic communities on north-facing and south-facing slopes.

On divides, peaks, and ridge crests, rapid drainage dries the soil, which is also more exposed to sunlight and drying winds. By contrast, the valley floors are wetter because water converges there. In humid climates, the ground water table in valley floors may lie close to or at the ground surface, producing marshes, swamps, ponds, and bogs.

Edaphic Factors

Soils can vary widely from one small area to the next, influencing the local distribution of plants and animals. Edaphic factors are connected to the soil. For example, sandy soils store less water than soils with abundant silt and clay, so they are often home to xerophytes. If there's a high amount of organic matter in the soil, then the soil will be rich in nutrients and will harbor more plant species. The relationship can work in the opposite direction, too—biota can change soil conditions, as when a prairie grassland builds a rich, fertile soil beneath it.

Disturbance

Disturbance includes fire, flood, volcanic eruption, storm waves, high winds, and other infrequent catastrophic events that damage or destroy ecosystems and modify habitats. Although disturbance can greatly alter the nature of an ecosystem, it is often part of a natural cycle of regeneration that gives short-lived or specialized species the opportunity to grow and reproduce.

For example, fire will strike most forests sooner or later. In many cases, the fire is beneficial. It cleans out the understory and consumes dead and decaying organic matter while leaving most of the overstory trees untouched.

Fire helps expose mineral soil on the forest floor and fertilizes it with new ash, providing a productive environment for dormant seeds. In addition, shrubs and forbs no longer shade the soil from sunlight. Among tree species, pines are typically well adapted to germinating under such conditions. In fact, the jack pine of eastern North America and the lodgepole pine of the intermountain West have cones that remain tightly closed until the heat of a fire opens them, allowing the seeds to be released. Fires also preserve grasslands. Grasses are fire-resistant because they have extensive root systems below ground and germinal buds located at or just below the surface. But woody plants that might otherwise invade grassland areas are not so resistant and are usually killed by grass fires. In many regions, active fire suppression has reduced the frequency of burning to well below natural levels. That may sound like a good thing, but in forests, this causes dead wood to build up on the forest floor. So, when a fire does start, it's destructive—burning hotter and more rapidly and consuming the crowns of many overstory trees.

Flooding is another important disturbance. It displaces animal communities and also deprives plant roots of oxygen. Where flooding brings a swift current, mechanical damage rips limbs from trees and scours out roots. High winds are another significant factor that can topple individual trees as well as whole forest stands.

Interactions Among Species

Species don't react with just their physical surroundings. They also interact with each other. That interaction may benefit at least one of the species, be negative to one or both species, or have no effect on either species.

Competition is a negative interaction. It happens whenever two species need a common resource that is in short supply. Both populations suffer from lowered growth rates than they would have had if only one species were present. Sometimes one species will win the competition and crowd out its competitor. At other times, the two species may remain in competition indefinitely.

Competition is an unstable situation. If a genetic strain within one of the populations emerges that can use a substitute resource, its survival rate will be higher than that of the remaining strain, which still competes. The original strain may become extinct. In this way, evolutionary mechanisms tend to reduce competition among species.

Predation and parasitism are other negative interactions between species. Predation occurs when one species feeds on another. There are obvious benefits for the predator species, which obtains energy for survival, but, of course, the interaction has a negative outcome for the prey species. Parasitism occurs when one species gains nutrition from another, typically when the parasite organism invades or attaches to the body of the host in some way.

Although we tend to think that predation and parasitism are always negative—benefiting one species at the expense of the other—in some cases it works out well for the prey or host populations, too, in the long run. A classic example is the rise and fall of the deer herd on the Kaibab Plateau north of the Grand Canyon in Arizona. Predation and parasitism will also remove the weaker individuals, improving the attacked species' genetic composition.

Another type of negative interaction between species is herbivory. When animals graze, they can reduce the viability of the plant species population. Although some plants can maintain themselves well in the face of grazing pressure, others are quite sensitive to overgrazing. Allelopathy, also a negative interaction, occurs when one plant species produces chemical toxins that inhibit other species.

We mentioned the symbiotic relationship between legumes and the nitrogen-fixing Rhizobium bacteria— which benefits both species—when we looked at the nitrogen cycle, earlier in the chapter. Symbiosis includes three types of positive interactions: commensalism, protocooperation, and mutualism. In commensalism, one of the species is benefited and the other is unaffected. Sometimes the relationship benefits both parties but isn't essential for their survival. This type of relationship is called protocooperation. If the relationship reaches a point where one or both species cannot survive alone, it's called mutualism. The relationship between the nitrogen-fixing bacterium Rhizobium and legumes is a classic example of mutualism because Rhizobium needs the plant for its own survival.

6

Issues related to Human Races in India and World

INDIA'S CASTE SYSTEM

India has a huge population encompassing many obvious physical variations, from light skins to some of the darkest in the world and a wide variety of hair textures and facial features. Such variations there, as elsewhere, are a product of natural selection in tropical and semitropical environments, of genetic drift among small populations, and of historical migrations and contact between peoples.

The Hindu sociocultural system was traditionally divided into castes that were exclusive, hereditary, and endogamous. They were also ranked and unequal and thus appeared to have many of the characteristics of "race."

But the complex caste system was not based primarily on skin colour, as castes included people of all physical variations. Nor was it based on a "scientific" ideology of superiority or inferiority, although late 19th-century pseudoscientific analyses attempted to explain the system's longevity.

Although some early 20th-century European scholars tried to divide the Indian and other Asian peoples into races, their efforts were hindered not only by the complexity of physical variations in India, parts of Southeast Asia, and Melanesia but by the developing fields of science.

Castes were, and are still, occupational groups as well as elements in a religious system that accords different values and different degrees of purity to different occupations. They also are the main regulators of marriage and inheritance rights. Some castes were originally small-scale tribal groups who were incorporated into the Hindu kingdoms. It has been noted that there are thousands of castes in India and many different ways of ranking them, including through such cultural features as food taboos and sharing obligations, but none derive from skin colour or "race."

Caste discrimination has been outlawed in India, although it remains deeply rooted in the cultures of ordinary people. Moreover, democratic values, the human rights movement, and the processes of industrialization have affected the rigid social caste system of India and led in some areas to a blurring of caste boundaries and a decline in the importance of caste identity.

Japan's minority peoples

A few ethnographic studies have suggested that a form of racial ideology has developed independently of the West in some traditional societies such as that of Japan, where various minority peoples, notably the *burakumin* and the Ainu, have been victimized and exploited by the dominant society. The *burakumin*, the former outcastes, have suffered from various forms of discrimination because of folk myths about their "polluted blood," a discourse that has historical origin but no biological reality. Discrimination against them has been made possible by identifying group membership on the basis of descent—in modern times this discrimination is most pronounced in marriage, but historically it also affected housing and employment—and "traditional" occupations—such as butchering animals or disposing of corpses—which had been considered undesirable for the centuries during which Buddhism was a dominant religion. Medieval documents reveal that long before Japan imported Western racial ideology in the modern age, they were portrayed as being of a different *shu* ("race"), and discrimination against them was institutionalized and legalized. Although the *burakumin* were declared by law in 1871 to be of equal status, prejudice against them persisted into the 21st century.

The Ainu are an indigenous people who once occupied the northern part of Japan. Today they inhabit Hokkaido and various other parts of Japan as well, including the greater Tokyo region. Contemporary scholars agree that both the Ainu and the more dominant Japanese share the ancestral JM mon culture. The old theory that claimed that the Ainu bore greater resemblance to Europeans than to Asians, as seen in their abundance of body hair and rounder eyes, is no longer accepted.

It should be noted that when the indigenous racial worldview that developed independently in premodern Japan merged with Western scientific racism after the 1868 Meiji Restoration, the "biological differences" from the dominant Japanese of such groups as the Ainu, the Okinawans, and the *burakumin*, which physical anthropologists "found" or redefined through various body measures, were used to justify both the government's assimilation policies and discriminatory practices.

In the post-World War II era, discrimination against Koreans, one of the largest minorities in contemporary Japan, has been a major issue of racism. Ethnic Koreans are forced to choose between giving up various resources available only to Japanese citizens so that they can maintain their Korean identities and giving up recognition of their Korean identity in order to receive Japanese citizenship.

RACE IN ASIA

A crucial element in understanding the various ideas of race in Asia is that morphological (phenotypic) differences do not always play the major role in determining racial differences, although exposure to Western definitions of race and forms of racism since the mid-19th century have made morphological differences more important than they once were.

As elsewhere, Asian ideologies of status arose with the development of agriculture and the accompanying territorial expansions of imperial states. Traditionally, Asian notions of difference tended to be shaped by criteria such as descent, religion, and language rather than by physical characteristics. The historical discrimination against the *burakumin* in Japan and the demarcation between ethnic Chinese and "barbarians" in the Qing dynasty (1644–1911/12), for example, were already as rigidly institutionalized in the premodern period as the anti-Semitism found throughout European history.

Thus, perceptions of skin colour did not have the same significance or connotation as in Europe and the Americas. In India many of the supreme deities, including Shiva, Rama, and Krishna, were depicted as dark blue or black—colours that are said to symbolize the dark clouds that bring rain to the fields and, by implication, the prosperity that accompanies a plentiful harvest. Japanese paintings depicting encounters with European missionaries in the 17th century emphasize differences in the shapes of noses and hair and eye colour but depict the skin tone of visiting Europeans as the same as that of Japanese. Yet, in various Asian regions, Europeans are sometimes referred to as "red faces" or "red people," while in other cases Chinese and Japanese are labeled as "white people."

The introduction of European theories of race in the 19th century had enormous impact almost everywhere in Asia—as it did in the rest of the world. Recognized as part of Western knowledge, and thus symbolizing modernity, racial classification theories became a new tool of authority for European colonizers and Asian leaders alike. These ideas were invoked to justify the hierarchical relationship between "white" colonizers and "yellow" or "brown" Asians in general, as well as that between high- and low-status Asians.

Colonizers were preoccupied with race (a term they rarely defined, and then inconsistently) and began to use it as a gloss for the aforementioned forms of traditional Asian social differentiation. By the mid-1800s colonial Europeans were employing techniques such as ethnographic research, mapping, and census taking to describe Asia's various "races." In Japan, Western racial classification theories, along with Western sciences, started to become known by the late Tokugawa period (1603–1867) through missionaries and Dutch writings. They spread widely throughout the country after the Meiji Restoration in 1868, and Johann Friedrich Blumenbach's five classifications (Caucasian, Mongolian, Malayan, Ethiopian, and American), for instance, appeared in elementary school textbooks as early as the 1870s. Blumenbach's classifications were introduced to China by missionaries and by Chinese intellectuals who had studied Japan in the late 19th century. About the same time, the Han Chinese started to celebrate their descent from Huangdi (*c.* 2700 BCE) and to reclaim their mythical Yellow Emperor as the founder of Chinese civilization—a narrative that bolstered the Chinese arguments according to which they were the prime race within the "yellow" race.

There was a relatively short time span in Asia between the acceptance of a Westernized racial classificatory system and the adoption of social Darwinism, a philosophy positing that "weak" groups or races will eventually be driven to extinction by those that are more "fit." Chinese and Japanese intellectuals—the former in the social chaos partly rooted in the aftermath of the Opium Wars, and the latter on the brink of modernization—did not critically question the Eurocentric and bigoted nature of the Western conception of race or of social Darwinism. In fact, "racial improvement" through amalgamation with the white race was proposed by some influential thinkers in both countries. Various anthropometric methods were employed or invented in China and Japan under the influence of Western scientific racism and were soon used to "verify" the "low" racial status of domestic marginalized groups and of the "barbarian" races outside national boundaries. Such findings were soon used to justify the state-led subjugation of these groups.

Western racial characterizations spread to other parts of Asia in the latter half of the 19th century. These classifications not only justified the superior social position of European colonizers in regard to Asian subordinates but also evolved into detailed subdivisions between colonial subjects themselves, wherein the elite characterized "tribes" and other marginalized groups as "barbarian" and "primitive." In colonial India the British anthropologists who conducted ethnographic research built reciprocal relationships with Indian elites and went so far as to construct a defense of the country's caste system. This defense was based on the "scientific" analysis of cranial differences between members of different castes. The findings were taken seriously at the time, however, and indicated that Bengali upper castes were Aryan in origin and that the lower castes such as foragers and pastoralists were, under the precepts of social Darwinism, destined to die out. Thus, in the closing decades of the 19th century, the idea of race gained a particular meaning in colonial Southeast Asia and India—a meaning that supported public policies that were beneficial to colonizers and the ruling classes and very injurious to nonelites, who were presumed to be on the path to extinction.

European racial ideology was put to a different use in independent Southeast Asian countries such as Siam (now Thailand). There, in the late 19th century, elites seeking to create a modern state employed European ideas of race to position within a global racial and civilizational hierarchy not only their own peoples but also those of neighbouring states. They located each group in a hierarchy according to perceived degrees of "civilization." Western studies tracing the common linguistic origins of various cultures led to the conceptualization of a Thai "nation" or Thai "race" that consisted of all Thai-speaking peoples living within or beyond Siam's national borders. As elsewhere, public policy was affected by concepts of race: Siam initiated assimilation and integration policies in the early 20th century as part of a pan-Thai movement, intending to build a Thai empire that would politically and geographically unite all peoples of the Thai race into one nation-state.

Two contrasting censuses taken in Malaysia in 1911 reflect sharp differences in race consciousness: while the Straits Settlements census used alphabetic ordering starting with "Aboriginees of the Peninsula," the Federated Malay States (Negeri

Sembilan, Pahang, Perak, and Selangor) census listed categories by racial classification, with Europeans appearing at the top, followed by Eurasians, Malays, Chinese, Indians, and "other." After 1911 ethnic classification generally followed the latter pattern.

The "Yellow Race" began to be perceived as a threat to "White civilized countries," particularly after Japan's victory in the Russo-Japanese War of 1904–05, which was sensationally cast in the West as the first loss of the white race to a nonwhite race in centuries. Resistance to the mounting European invasion of China and other parts of Asia and Euro-American racism toward the burgeoning Asian population grew and intensified. A commonly shared and mutually reinforcing conviction developed between the Chinese and the Japanese: they saw themselves as different branches of a single "yellow" race that was involved in a pan-Asiatic struggle against Western imperialism. Simultaneously, they projected their own prejudices against the "brown" races of other Asian countries, whom they regarded as barbarian and backward.

Yet each country also interpreted the situation to its own benefit. China believed its central position within the "yellow" race was to counteract the hegemony of the "white" race while at the same time advocating that the "red," "brown," and "black" races be allowed (under the auspice of social Darwinism) to pass into extinction. Japan, on the other hand, claimed its destiny was to be the leading race in Asia. Japan used this concept to justify its invasion of Manchuria in 1931–32 and later to expand its reach across different Asian countries in the name of the Greater East Asia Co-Prosperity Sphere in an attempt to control these regions and obtain much-needed natural resources.

In the period following World War II, as Asian countries embarked on nation building, perceptions of race have played essential roles in defining their national identities and shaping their external relations, particularly with Europe and America. The advancement of Westernization and the wide presence of U.S. military bases in Asia have significantly affected aesthetic ideals among Asian peoples. In different regions of contemporary Asia, lighter skin and other phenotypes that are traditionally considered traits of Europeans are now regarded as more desirable. Asian countries are not exempt from trends in global migration since the late 20th century. Even a society such as that of Korea, which is considered to be one of the most "homogeneous" in the world, is facing increasing immigration and issues of multiculturalism.

Nongovernmental organizations (NGOs) and government-sponsored multicultural policies have helped spread the notions of civil rights and antiracism in Asia. However, the influence of neoliberal economic policies has also affected immigrants and minorities, further marginalizing them economically and socially. Racism today sometimes appears not just within a nation-state framework but also in complex transnational and global frameworks, thus making it more difficult to combat. Since the turn of the 21st century, transnational alliances to combat racism have been formed, such as that between the *burakumin* in Japan and the Dalits (or "untouchables") in India, as exemplified in the UN World Conference Against Racism and Anti-Discrimination (2001), held in Durban, S.Af.

On the other hand, the global hegemony of neoliberalism after the end of the Cold War has made it more difficult to combat racism because of the emergence of new divisions within the same racialized group. While those with corresponding cultural resources may become power brokers and represent their communities vis-à-vis the multicultural state apparatus, the poor are increasingly exploited and are pushed into informal and insecure forms of employment. Meanwhile, a new nonwhite economic elite has risen to global power while maintaining diasporic connections across the world. Whether all these developments together will result in a change in the global racial hierachies remains to be seen.

Latin America

Race is a highly variable construct in Latin America, where racial ideas typically refer to "blacks" (Africans brought to the region as slaves and their descendants), "whites" (European colonists who conquered and settled the region and their descendants), and "Indians" (the indigenous population that inhabited the region before European conquest). A key feature of race in Latin America is the idea of *mestizaje* or *mesti agem* ("mixture" in Spanish and Portuguese, respectively), which refers to the biological and cultural blending that has taken place among these three populations.

The colonial period

The process of mixture in Latin America began with European colonization. It was conditioned by factors that varied from one region to the next, such as the number and nature of an area's indigenous societies, the origins and goals of its colonists, and the extent and type of slavery they practiced.

Before the European conquest, the American Indian population was quite diverse and ranged from densely settled, politically stratified societies with urban centres (as with the Inca and Aztec empires) to mobile, egalitarian hunting and gathering cultures. Although the indigenous peoples of Latin America were quickly decimated by European diseases and ill treatment, the indigenous groups that had been populous at the time of contact generally remained relatively large. In these cases, most notably in the central Andes and central Mexico, Spanish colonists primarily enslaved native peoples, although they also used some enslaved Africans. In other areas, such as Brazil, Cuba, and Colombia, indigenous populations had plummeted so greatly that the Portuguese and Spanish colonists imported large numbers of African slaves.

Genetic and cultural mixing between Europeans, Africans, and indigenous peoples started almost immediately upon contact, although some elite Europeans disavowed it. The offspring of mixed unions were recognized as socially distinct from their parents, and new social classifications proliferated. Although *mestizo* ("mixed person") was a general label, it often referred specifically to people of indigenous and European heritage, while the term *mulato* ("mulatto") usually referred to a person of African and European descent. Labels multiplied as time went on, as with *zambo* (black-indigenous mix) and *pardo* (literally, "brown person," commonly used to denote a person of African and European descent). Spanish colonists attempted to systematize a hierarchy of socio-racial classes, known as a *sociedad de castas* ("society of castes, or breeds"). Portuguese colonists were less pedantic about this.

In all cases, mixture occurred in a setting in which Europeans were socially, economically, and militarily dominant and thus able to exploit black and indigenous labour and to enforce—or at least attempt to enforce—cultural changes in such areas as religious practice. However, many black and indigenous people resisted the colonial powers. They mounted many rebellions, and sizeable numbers escaped to the hinterlands, where they joined or rejoined extant communities or began new settlements.

Postcolonial society

By the mid-19th century most Latin American countries had become independent republics and abolished slavery. Important exceptions were Brazil, Cuba, and Puerto Rico, where slavery persisted until the 1880s, although by then most slaves had already been freed. Elites were keen to define their new nations' identities in a positive light but had difficulty reconciling the mixed nature of their populations with the era's popular, but since disproved, theories about the supposed biological inferiority of people of colour.

Especially around the turn of the 20th century, some Latin Americans responded to this dilemma by invoking a notion of "progressive mixture." This theory admitted that the national populations of Latin America were mixed but also assumed that the region was moving toward a "superior" state of increasing "whiteness." Many countries encouraged European immigration in order to hasten this supposed process of *blanqueamiento* ("whitening"). The beliefs and practices of elites in countries with large indigenous populations (e.g., Mexico) became quite contradictory: they tended to glorify the indigenous past in ideologies of *indigenismo* while still envisaging a future of integration and mixedness, all the while discriminating against extant indigenous peoples. Many Latin American intellectuals tried to distance themselves from Euro-American theories of race by asserting that mixture had created a tolerant society in which racism was not an issue and in which biology played little part in defining social identities. This image of "racial democracy" was made in explicit contrast to the racial segregation of the United States and persisted into the 21st century. In everyday practice, however, Latin American ideas about "race" continued to play an important role: although identity categories such as "black," "Indian," "white," and "mestizo" were recognized as highly variable and predominantly cultural, they nonetheless continued to be informed by ideas about descent (in terms of some internal "essence") and the body (in terms of appearance).

An example from Brazil helps to illustrate the complex ways that these issues played out in everyday life: much evidence collected since the 1950s indicates that, despite the indeterminacy of "black" as a collective identity, substantial racial inequality exists and is maintained in part by continuing discrimination against individual blacks. Other evidence, for example, from Colombia, Guatemala, and Peru, indicates that positive notions about physical and cultural mixture have continued to coexist with ideas about the superiority of whiteness and the inferiority of blackness and indigenousness.

In the late 20th century, several Latin American countries redefined their national identities, moving away from ideas of *blanqueamiento* and toward an official recognition and celebration of cultural and ethnic plurality. This was partly in response to indigenous and, to a lesser extent, black political activism that, building on long-standing traditions of resistance, flowered from the 1960s. The term *race* rarely occurs in this new discourse, yet the same categories—black, white, Indian—are in evidence. These developments have reaffirmed black and indigenous identities, especially in the public realm and when particular rights—most importantly, to land—are tied to what is now called "ethnicity." Although indigenous peoples have long had special land reserves in many parts of Latin America, it was only at the turn of the 21st century, most notably in Colombia, that the possibility of black communities applying for reserve land emerged.

The impact of these developments on Latin American ideas of race is not clear. Despite changes over the long term, the key trope of "mixture" has remained a vital (if publicly de-emphasized) part of Latin American national identities. In the past this trope did not erase the presence of blacks and indigenous peoples, but it did marginalize them—sometimes to the point of near invisibility. Although an emphasis on multiculturalism has helped to increase the visibility of these groups, the question of whether such developments will help to reduce their social, economic, and political marginality remains unanswered.

"RACE" AND THE REALITY OF HUMAN PHYSICAL VARIATION

Scientists have known for many decades that there is little correlation between "race," used in its popular sense, and actual physical variations in the human species. In the United States, for example, the people identified as African Americans do not share a common set of physical characteristics. There is a greater range of skin colours, hair colours and textures, facial features, body sizes, and other physical traits in this category than in any other human aggregate identified as a single race. Features of African Americans vary from light skins, blue or gray eyes, and blond hair to dark skins, black eyes, and crinkly hair and include every range and combination of characteristics in between. American custom has long classified any person with known African ancestry as black, a social mandate often called the "one-drop rule." This principle not only attests to the arbitrary nature of black racial identity, but it was also presumed to keep those classified as racially "white" pure and untainted by the "blood" of low-status and inferior races. This rule has not applied to other "racial" mixtures, such as children born of white and Asian parents, although some of these children have suffered discrimination because of physical similarities to their lower-status parent. All this gives clear evidence of the socially arbitrary nature of race categories in North America. Other types of anomalies have frequently appeared in efforts to classify "racial" populations around the world. Whereas British scholars, for example, tend to separate East Indians into their own racial category (during the colonial period, natives of India, Burma, Melanesia, and Australia were, and still are, called "blacks"), American scholars have usually included East Indians in the "Caucasian" category to differentiate them from American blacks. Light-skinned Indians usually from northern India have been accepted as "white," but very dark Indians have sometimes experienced colour discrimination in the United States.

Since World War II, travel and immigration have greatly increased the contact of Western peoples with a wide variety of peoples throughout the world. Contact with peoples of the South Pacific and Southeast Asia, as well as with peoples from several areas of Africa and the Middle East, has shown that most of these people do not neatly fit into existing racial stereotypes. Some appear to have a mixture of Asian and African or European and African physical characteristics. Others, such as Melanesians, can easily be mistaken for Africans or black Americans. More anomalous are native Australians, some of whom have light or blond wavy hair combined with dark skins. Many Americans are recognizing that the social categories of race as evolved in the United States are inadequate for encompassing such peoples who, indeed, do not share the social history of racial minorities in the United States.

In the 1950s and '60s the United States began experiencing an influx of new immigrants from Latin America. Spanish and Portuguese colonial societies exhibited very different attitudes toward physical differences. Even before Christopher Columbus set sail, the Mediterranean world had long been a world of heterogeneous peoples. Africans, southern Europeans, and peoples of the Middle East have interacted and interbred over thousands of years, as long as humans have occupied these regions. The Iberian peoples brought their customs and habits to the New World. There, as described above, intermating among Europeans, Africans, and Native Americans soon began to produce a population of "mixed" peoples. The descendants of these peoples who entered the United States since the mid-20th century further confound "racial" categories for those who believe in them.

U.S. military personnel fighting in the Persian Gulf region were startled to see that many Saudi Arabians, Yemenis, Omanis, and other peoples in the Middle East resembled African Americans or Africans in their skin colour, hair texture, and facial features. Many Southeast Asians and Middle Easterners have found that they are frequently mistaken for blacks in America. Some American Indians are mistaken for Chinese, Japanese, or other Asian ethnic groups on the basis of their skin colour, eye structure, and hair colour and texture. Some Central and South Americans and many Puerto Ricans are perceived as Arabs. In like manner, many Arab Americans or Persians are thought to be Latinos. "Race" is, indeed, in the eye of the beholder.

Clearly, physical features are insufficient clues to a person's ethnic identity. They reveal nothing about a person's culture, language, religion, and values. Sixth-generation Chinese Americans have American ethnicity; many know little or nothing about traditional Chinese culture, just as European Americans and African Americans may know little or nothing about the cultures of their ancestors. Moreover, all cultures change, and they do so independently of the biogenetic features of their carriers.

RACE (HUMAN CATEGORIZATION)

A race is a grouping of humans based on shared physical or social qualities into categories generally viewed as distinct by society. The term was first used to refer to speakers of a common language and then to denote national affiliations. By the 17th century the term began to refer to physical (phenotypical) traits. Modern scholarship regards race as a social construct, an identity which is assigned based on rules made by society. While partially based on physical similarities within groups, race does not have an inherent physical or biological meaning.

Social conceptions and groupings of races vary over time, involving folk taxonomies that define essential types of individuals based on perceived traits. Scientists consider biological essentialism obsolete, and generally discourage racial explanations for collective differentiation in both physical and behavioral traits.

Even though there is a broad scientific agreement that essentialist and typological conceptualizations of race are untenable, scientists around the world continue to conceptualize race in widely differing ways, some of which have essentialist implications. While some researchers use the concept of race to make distinctions among fuzzy sets of traits or observable differences in behaviour, others in the scientific community suggest that the idea of race often is used in a naive or simplistic way, and argue that, among humans, race has no taxonomic significance by pointing out that all living humans belong to the same species, *Homo sapiens*, and (as far as applicable) subspecies, *Homo sapiens sapiens*.

Since the second half of the 20th century, the association of race with the ideologies and theories of scientific racism has led to the use of the word *race* itself becoming problematic. Although still used in general contexts, *race* has often been replaced by less ambiguous and loaded terms: *populations*, *people(s)*, *ethnic groups*, or *communities*, depending on context.

Defining race

Modern scholarship views racial categories as socially constructed, that is, race is not intrinsic to human beings but rather an identity created, often by socially dominant groups, to establish meaning in a social context. Different cultures define different racial groups, often focused on the largest groups of social relevance, and these definitions can change over time.

- In South Africa, the Population Registration Act, 1950 recognized only White, Black, and Coloured.
- The government of Myanmar recognizes eight "major national ethnic races".

- The Brazilian census classifies people into brancos (whites), pardos (multiracial), pretos (blacks), caboclos, amarelos (Asians), and indigenous, though many people use different terms to identify themselves.
- The United States Census Bureau proposed but then withdrew plans to add a new category to classify Middle Eastern and North African peoples in the U.S. Census 2020, over a dispute over whether this classification should be considered a white ethnicity or a separate race.
- Legal definitions of whiteness in the United States used before the civil rights movement were often challenged for specific groups.
- Historical race concepts have included a wide variety of schemes to divide local or worldwide populations into races and sub-races.

The establishment of racial boundaries often involves the subjugation of groups defined as racially inferior, as in the one-drop rule used in the 19th-century United States to exclude those with any amount of African ancestry from the dominant racial grouping, defined as "white". Such racial identities reflect the cultural attitudes of imperial powers dominant during the age of European colonial expansion. This view rejects the notion that race is biologically defined.

According to geneticist David Reich, "while race may be a social construct, differences in genetic ancestry that happen to correlate to many of today's racial constructs are real." These biological differences in geographic ancestral populations are not consistent with zoological definitions of race, and there are no "sharp, categorical distinctions".

Although commonalities in physical traits such as facial features, skin color, and hair texture comprise part of the race concept, this linkage is a social distinction rather than an inherently biological one. Other dimensions of racial groupings include shared history, traditions and language. For instance, African-American English is a language spoken by many African Americans, especially in areas of the United States where racial segregation exists. Furthermore, people often self-identify as members of a race for political reasons.

When people define and talk about a particular conception of race, they create a social reality through which social categorization is achieved. In this sense, races are said to be social constructs. These constructs develop within various legal, economic, and sociopolitical contexts, and may be the effect, rather than the cause, of major social situations. While race is understood to be a social construct by many, most scholars agree that race has real material effects in the lives of people through institutionalized practices of preference and discrimination.

Socioeconomic factors, in combination with early but enduring views of race, have led to considerable suffering within disadvantaged racial groups. Racial discrimination often coincides with racist mindsets, whereby the individuals and ideologies of one group come to perceive the members of an outgroup as both racially defined and morally inferior. As a result, racial groups possessing relatively little power often find themselves excluded or oppressed, while hegemonic individuals and institutions are charged with holding racist attitudes. Racism has led to many instances of tragedy, including slavery and genocide.

In some countries, law enforcement uses race to profile suspects. This use of racial categories is frequently criticized for perpetuating an outmoded understanding of human biological variation, and promoting stereotypes. Because in some societies racial groupings correspond closely with patterns of social stratification, for social scientists studying social inequality, race can be a significant variable. As sociological factors, racial categories may in part reflect subjective attributions, self-identities, and social institutions.

Scholars continue to debate the degrees to which racial categories are biologically warranted and socially constructed. For example, in 2008, John Hartigan, Jr. argued for a view of race that focused primarily on culture, but which does not ignore the potential relevance of biology or genetics. Accordingly, the racial paradigms employed in different disciplines vary in their emphasis on biological reduction as contrasted with societal construction.

In the social sciences, theoretical frameworks such as racial formation theory and critical race theory investigate implications of race as social construction by exploring how the images, ideas and assumptions of race are expressed in everyday life. A large body of scholarship has traced the relationships between the historical, social production of race in legal and criminal language, and their effects on the policing and disproportionate incarceration of certain groups.

ANCESTRALLY DIFFERENTIATED POPULATIONS

Cladistics is another method of classification. A clade is a taxonomic group of organisms consisting of a single common ancestor and all the descendants of that ancestor. Every creature produced by sexual reproduction has two immediate lineages, one maternal and one paternal. Whereas Carolus Linnaeus established a taxonomy of living organisms based on anatomical similarities and differences, cladistics seeks to establish a taxonomy—the phylogenetic tree—based on genetic similarities and differences and tracing the process of acquisition of multiple characteristics by single organisms. Some researchers have tried to clarify the idea of race by equating it to the biological idea of the clade. Often mitochondrial DNA or Y chromosome sequences are used to study ancient human migration paths. These single-locus sources of DNA do not recombine and are inherited from a single parent. Individuals from the various continental groups tend to be more similar to one another than to people from other continents, and tracing either mitochondrial DNA or non-recombinant Y-chromosome DNA explains how people in one place may be largely derived from people in some remote location.

Often taxonomists prefer to use phylogenetic analysis to determine whether a population can be considered a subspecies. Phylogenetic analysis relies on the concept of derived characteristics that are not shared between groups, usually applying to populations that are allopatric (geographically separated) and therefore discretely bounded. This would make a subspecies, evolutionarily speaking, a clade – a group with a common evolutionary ancestor population. The smooth gradation of human genetic variation in general tends to rule out any idea that human population groups can be considered monophyletic (cleanly divided), as there appears to always have been considerable gene flow between human populations. Rachel Caspari (2003) have argued that clades are by definition monophyletic groups (a taxon that includes *all* descendants of a given ancestor) and since no groups currently regarded as races are monophyletic, none of those groups can be clades.

For the anthropologists Lieberman and Jackson (1995), however, there are more profound methodological and conceptual problems with using cladistics to support concepts of race. They claim that "the molecular and biochemical proponents of this model explicitly use racial categories *in their initial grouping of samples*".

For example, the large and highly diverse macroethnic groups of East Indians, North Africans, and Europeans are presumptively grouped as Caucasians prior to the analysis of their DNA variation. This is claimed to limit and skew interpretations, obscure other lineage relationships, deemphasize the impact of more immediate clinal environmental factors on genomic diversity, and can cloud our understanding of the true patterns of affinity. They argue that however significant the empirical research, these studies use the term race in conceptually imprecise and careless ways. They suggest that the authors of these studies find support for racial distinctions only because they began by assuming the validity of race. "For empirical reasons we prefer to place emphasis on clinal variation, which recognizes the existence of adaptive human hereditary variation and simultaneously stresses that such variation is not found in packages that can be labeled *races*."

These scientists do not dispute the importance of cladistic research, only its retention of the word race, when reference to populations and clinal gradations are more than adequate to describe the results.

Fixation Index

The population geneticist Sewall Wright developed one way of measuring genetic differences between populations known as the Fixation index, which is often abbreviated to F_{ST}. This statistic is often used in taxonomy to compare differences between any two given populations by measuring the genetic differences among and between populations for individual genes, or for many genes simultaneously. It is often stated that the fixation index for humans is about 0.15. This translates to an estimated 85% of the variation measured in the overall human population is found within individuals of the same population, and about 15% of the variation occurs between populations. These estimates imply that any two individuals from different populations are almost as likely to be more similar to each other than either is to a member of their own group. Richard Lewontin, who affirmed these ratios, thus concluded neither "race" nor "subspecies" were appropriate or useful ways to describe human populations. However, others have noticed that group variation was relatively similar to the variation observed in other mammalian species.

Wright himself believed that values >0.25 represent very great genetic variation and that an F_{ST} of 0.15–0.25 represented great variation. However, about 5% of human variation occurs between populations within continents, therefore F_{ST} values between continental groups of humans (or races) of as low as 0.1 (or possibly lower) have been found in some studies, suggesting more moderate levels of genetic variation. Graves (1996) has countered that F_{ST} should not be used as a marker of subspecies status, as the statistic is used to measure the degree of differentiation between populations, although see also Wright (1978).

In an ongoing debate, some geneticists argue that race is neither a meaningful concept nor a useful heuristic device, and even that genetic differences among groups are biologically meaningless, because more genetic variation exists within such races than among them, and that racial traits overlap without discrete boundaries.

Jeffrey Long and Rick Kittles give a long critique of the application of F_{ST} to human populations in their 2003 paper "Human Genetic Diversity and the Nonexistence of Biological Races". They find that the figure of 85% is misleading because it implies that all human populations contain on average 85% of all genetic diversity. They claim that this does not correctly reflect human population history, because it treats all human groups as independent. A more realistic portrayal of the way human groups are related is to understand that some human groups are parental to other groups and that these groups represent paraphyletic groups to their descent groups. For example, under the recent African origintheory the human population in Africa is paraphyletic to all other human groups because it represents the ancestral group from which all non-African populations derive, but more than that, non-African groups only derive from a small non-representative sample of this African population. This means that all non-African groups are more closely related to each other and to some African groups (probably east Africans) than they are to others, and further that the migration out of Africa represented a genetic bottleneck, with much of the diversity that existed in Africa not being carried out of Africa by the emigrating groups. This view produces a version of human population movements that do not result in all human populations being independent; but rather, produces a series of dilutions of diversity the further from Africa any population lives, each founding event representing a genetic subset of its parental population. Long and Kittles find that rather than 85% of human genetic diversity existing in all human populations, about 100% of human diversity exists in a single African population, whereas only about 70% of human genetic diversity exists in a population derived from New Guinea. Long and Kittles argued that this still produces a global human population that is genetically homogeneous compared to other mammalian populations.

Brazil

Compared to 19th-century United States, 20th-century Brazil was characterized by a perceived relative absence of sharply defined racial groups. According to anthropologist Marvin Harris, this pattern reflects a different history and different social relations.

Basically, race in Brazil was "biologized," but in a way that recognized the difference between ancestry (which determines genotype) andphenotypic differences. There, racial identity was not governed by rigid descent rule, such as the one-drop rule, as it was in the United States. A Brazilian child was never automatically identified with the racial type of one or both parents, nor were there only a very limited number of categories to choose from, to the extent that full siblings can pertain to different racial groups.

Self-reported ancestry of people from Rio de Janeiro, by race or skin colour (2000 survey)

Ancestry	*brancos*	*pardos*	*pretos*
European only	48%	6%	-
African only	–	12%	25%
Amerindian only	–	2%	-
African and European	23%	34%	31%
Amerindian and European	14%	6%	-
African and Amerindian	–	4%	9%
African, Amerindian and European	15%	36%	35%
Total	100%	100%	100%
Any African	38%	86%	100%

Over a dozen racial categories would be recognized in conformity with all the possible combinations of hair color, hair texture, eye color, and skin color. These types grade into each other like the colors of the spectrum, and none category stands significantly isolated from the rest. That is, race referred preferentially to appearance, not heredity, and appearance is a poor indication of ancestry, because only a few genes are responsible for someone's skin colour and traits: a person who is considered white may have more African ancestry than a person who is considered black, and the reverse can be also true about European ancestry. The complexity of racial classifications in Brazil reflects the extent of miscegenation in Brazilian society, a society that remains highly, but not strictly, stratified along colour lines. These socioeconomic factors are also significant to the limits of racial lines, because a minority of *pardos*, or brown people, are likely to start declaring themselves white or black if socially upward, and being seen as relatively "whiter" as their perceived social status increases (much as in other regions of Latin America).

Fluidity of racial categories apart, the "biologification" of race in Brazil referred above would match contemporary concepts of race in the United States quite closely, though, if Brazilians are supposed to choose their race as one among, Asian and Indigenous apart, three IBGE's census categories.

While assimilated Amerindians and people with very high quantities of Amerindian ancestry are usually grouped as *caboclos*, a subgroup of *pardos* which roughly translates as both mestizo and hillbilly, for those of lower quantity of Amerindian descent a higher European genetic contribution is expected to be grouped as a *pardo*.

In several genetic tests, people with less than 60-65% of European descent and 5-10% of Amerindian descent usually cluster with Afro-Brazilians (as reported by the individuals), or 6.9% of the population, and those with about 45% or more of Subsaharan contribution most times do so (in average, Afro-Brazilian DNA was reported to be about 50% Subsaharan African, 37% European and 13% Amerindian).

If a more consistent report with the genetic groups in the gradation of miscegenation is to be considered (e.g. that would not cluster people with a balanced degree of African and non-African ancestry in the black group instead of the multiracial one, unlike elsewhere in Latin America where people of high quantity of African descent tend to classify themselves as mixed), more people would report themselves as white and *pardo* in Brazil (47.7% and 42.4% of the population as of 2010, respectively), because by research its population is believed to have between 65 and 80% of autosomal European ancestry, in average (also >35% of European mt-DNA and >95% of European Y-DNA).

Ethnic groups in Brazil (census data)

Ethnic group	white	black	*pardo*
1872	3,787,289	1,954,452	4,188,737
1940	26,171,778	6,035,869	8,744,365
1991	75,704,927	7,335,136	62,316,064

Ethnic groups in Brazil (1872 and 1890)

Years	*whites*	*pardos*	*blacks*	*Indians*	*Total*
1872	38.1%	38.3%	19.7%	3.9%	100%
1890	44.0%	32.4%	14.6%	9%	100%

This is not surprising, though: While the greatest number of slaves imported from Africa were sent to Brazil, totalizing roughly 3.5 million people, they lived in such miserable conditions that male African Y-DNA there is significantly rare due to the lack of resources and time involved with raising of children, so that most African descent originarily came from relations between white masters and female slaves. From the last decades of the Empire until the 1950s, the proportion of the white population increased significantly while Brazil welcomed 5.5 million immigrants between 1821 and 1932, not much behind its neighbor Argentina with 6.4 million, and it received more European immigrants in its colonial history than the United States. Between 1500 and 1760, 700.000 Europeans settled in Brazil, while 530.000 Europeans settled in the United States for the same given time. Thus, the historical construction of race in Brazilian society dealt primarily with gradations between persons of majoritarily European ancestry and little minority groups with otherwise lower quantity therefrom in recent times.

HISTORICAL ORIGINS OF RACIAL CLASSIFICATION

Groups of humans have always identified themselves as distinct from neighboring groups, but such differences have not always been understood to be natural, immutable and global. These features are the distinguishing features of how the concept of race is used today. In this way the idea of race as we understand it today came about during the historical process of exploration and conquest which brought Europeans into contact with groups from different continents, and of the ideology of classification and typology found in the natural sciences. The term *race* was often used in a general biological taxonomic sense, starting from the 19th century, to denote genetically differentiated human populations defined by phenotype.

The modern concept of race emerged as a product of the colonial enterprises of European powers from the 16th to 18th centuries which identified race in terms of skin color and physical differences. This way of classification would have been confusing for people in the ancient world since they did not categorize each other in such a fashion. In particular, the epistemological moment where the modern concept of race was invented and rationalized lies somewhere between 1730 to 1790.

Colonialism

According to Smedley and Marks the European concept of "race", along with many of the ideas now associated with the term, arose at the time of the scientific revolution, which introduced and privileged the study of natural kinds, and the age of European imperialism and colonization which established political relations between Europeans and peoples with distinct cultural and political traditions. As Europeans encountered people from different parts of the world, they speculated about the physical, social, and cultural differences among various human groups. The rise of the Atlantic slave trade, which gradually displaced an earlier trade in slaves from throughout the world, created a further incentive to categorize human groups in order to justify the subordination of African slaves.

Drawing on sources from classical antiquity and upon their own internal interactions – for example, the hostility between the English and Irish powerfully influenced early European thinking about the differences between people – Europeans began to sort themselves and others into groups based on physical appearance, and to attribute to individuals belonging to these groups behaviors and capacities which were claimed to be deeply ingrained. A set of folk beliefs took hold that linked inherited physical differences between groups to inherited intellectual, behavioral, and moral qualities. Similar ideas can be found in other cultures, for example in China, where a concept often translated as "race" was associated with supposed common descent from the Yellow Emperor, and used to stress the unity of ethnic groups in China. Brutal conflicts between ethnic groups have existed throughout history and across the world.

Early taxonomic models

The first post-Graeco-Roman published classification of humans into distinct races seems to be François Bernier's *Nouvelle division de la terre par les différents espèces ou races qui l'habitent* ("New division of Earth by the different species or races which inhabit it"), published in 1684. In the 18th century the differences among human groups became a focus of scientific investigation. But the scientific classification of phenotypic variation was frequently coupled with racist ideas about innate predispositions of different groups, always attributing the most desirable features to the White, European race and arranging the other races along a continuum of progressively undesirable attributes. The 1735 classification of Carl Linnaeus, inventor of zoological taxonomy, divided the human species *Homo sapiens* into continental varieties of *europaeus*, *asiaticus*, *americanus*, and *afer*, each associated with a different humour: sanguine, melancholic, choleric, and phlegmatic, respectively. *Homo sapiens europaeus* was described as active, acute, and adventurous, whereas *Homo sapiens afer* was said to be crafty, lazy, and careless.

The 1775 treatise "The Natural Varieties of Mankind", by Johann Friedrich Blumenbach proposed five major divisions: the Caucasoid race, the Mongoloid race, the Ethiopian race (later termed *Negroid*), the American Indian race, and the Malayan race, but he did not propose any hierarchy among the races. Blumenbach also noted the graded transition in appearances from one group to adjacent groups and suggested that "one variety of mankind does so sensibly pass into the other, that you cannot mark out the limits between them".

From the 17th through 19th centuries, the merging of folk beliefs about group differences with scientific explanations of those differences produced what Smedley has called an "ideology of race". According to this ideology, races are primordial, natural, enduring and distinct.

It was further argued that some groups may be the result of mixture between formerly distinct populations, but that careful study could distinguish the ancestral races that had combined to produce admixed groups. Subsequent influential classifications by Georges Buffon, Petrus Camper and Christoph Meiners all classified "Negros" as inferior to Europeans. In the United States the racial theories of Thomas Jefferson were influential. He saw Africans as inferior to Whites especially in regards to their intellect, and imbued with unnatural sexual appetites, but described Native Americans as equals to whites.

Polygenism vs monogenism

In the last two decades of the 18th century, the theory of polygenism, the belief that different races had evolved separately in each continent and shared no common ancestor, was advocated in England by historian Edward Long and anatomist Charles White, in Germany by ethnographers Christoph Meiners and Georg Forster, and in France by Julien-Joseph Virey.

In the US, Samuel George Morton, Josiah Nott and Louis Agassiz promoted this theory in the mid-nineteenth century. Polygenism was popular and most widespread in the 19th century, culminating in the founding of the Anthropological Society of London (1863), which, during the period of the American Civil War, broke away from the Ethnological Society of London and its monogenic stance, their underlined difference lying, relevantly, in the so-called "Negro question": a substantial racist view by the former, and a more liberal view on race by the latter.

Modern scholarship

Models of human evolution

Today, all humans are classified as belonging to the species *Homo sapiens*. However, this is not the first species of homininae: the first species of genus *Homo*, *Homo habilis*, evolved in East Africa at least 2 million years ago, and members of this species populated different parts of Africa in a relatively short time. *Homo erectus* evolved more than 1.8 million years ago, and by 1.5 million years ago had spread throughout Europe and Asia. Virtually all physical anthropologists agree that *Archaic Homo sapiens* (A group including the possible species *H. heidelbergensis*, *H. rhodesiensis* and *H. neanderthalensis*) evolved out of African *Homo erectus* (*sensu lato*) or *Homo ergaster.* Anthropologists support the idea that anatomically modern humans (*Homo sapiens*) evolved in North or East Africa from an archaic human species such as *H. heidelbergensis* and then migrated out of Africa, mixing with and replacing *H. heidelbergensis* and *H. neanderthalensis* populations throughout Europe and Asia, and *H. rhodesiensis* populations in Sub-Saharan Africa (a combination of the Out of Africa and Multiregional models).

Biological classification

In the early 20th century, many anthropologists taught that race was an entirely biologically phenomenon and that this was core to a person's behavior and identity, a position commonly called racial essentialism. This, coupled with a belief that linguistic, cultural, and social groups fundamentally existed along racial lines, formed the basis of what is now called scientific racism. After the Nazi eugenics program, along with the rise of anti-colonial movements, racial essentialism lost widespread popularity. New studies of culture and the fledgling field of population genetics undermined the scientific standing of racial essentialism, leading race anthropologists to revise their conclusions about the sources of phenotypic variation. A significant number of modern anthropologists and biologists in the West came to view race as an invalid genetic or biological designation.

The first to challenge the concept of race on empirical grounds were the anthropologists Franz Boas, who provided evidence of phenotypic plasticity due to environmental factors, and Ashley Montagu, who relied on evidence from genetics. E. O. Wilson then challenged the concept from the perspective of general animal systematics, and further rejected the claim that "races" were equivalent to "subspecies".

Human genetic variation is predominantly within races, continuous, and complex in structure, which is inconsistent with the concept of genetic human races. According to Jonathan Marks,

By the 1970s, it had become clear that (1) most human differences were cultural; (2) what was not cultural was principally polymorphic – that is to say, found in diverse groups of people at different frequencies; (3) what was not cultural or polymorphic was principally clinal – that is to say, gradually variable over geography; and (4) what was left – the component of human diversity that was not cultural, polymorphic, or clinal – was very small. A consensus consequently developed among anthropologists and geneticists that race as the previous generation had known it – as largely discrete, geographically distinct, gene pools – did not exist.

Subspecies

The term *race* in biology is used with caution because it can be ambiguous. Generally, when it is used it is effectively a synonym of *subspecies*. (For animals, the only taxonomic unit below the species level is usually the subspecies; there are narrower infraspecific ranks in botany, and *race* does not correspond directly with any of them.) Traditionally, subspecies are seen as geographically isolated and genetically differentiated populations. Studies of human genetic variation show that human populations are not geographically isolated, and their genetic differences are far smaller than those among comparable subspecies.

In 1978, Sewall Wright suggested that human populations that have long inhabited separated parts of the world should, in general, be considered different subspecies by the criterion that most individuals of such populations can be allocated correctly by inspection. Wright argued that, "It does not require a trained anthropologist to classify an array of Englishmen, West Africans, and Chinese with 100% accuracy by features, skin color, and type of hair despite so much variability within each of these groups that every individual can easily be distinguished from every other." While in practice subspecies are often defined by easily observable physical appearance, there is not necessarily any evolutionary significance to these observed differences, so this form of classification has become less acceptable to evolutionary biologists. Likewise this typological approach to race is generally regarded as discredited by biologists and anthropologists.

Ancestrally differentiated populations (clades)

Some researchers have tried to clarify the idea of race by equating it to the biological idea of the clade. A clade is a taxonomic group of organisms consisting of a single common ancestor and all the descendants of that ancestor (a monophyletic group). Every creature produced by sexual reproduction has two immediate lineages, one maternal and one paternal. Whereas Carl Linnaeus established a taxonomy of living organisms based on anatomical similarities and differences, cladistics seeks to establish a taxonomy – the phylogenetic tree – based on genetic similarities and differences and tracing the process of acquisition of multiple characteristics by single organisms.

Philosopher Robin Andreasen (2000) proposes that cladistics can be used to categorize human races biologically, and that races can be both biologically real and socially constructed. Andreasen cites tree diagrams of relative genetic distances among populations published by Luigi Cavalli-Sforza as the basis for a phylogenetic tree of human races: "Cavalli-Sforza's research illustrates that it is possible to reconstruct human evolutionary history, and this means that it is possible to provide a cladistic definition of race" (p. S661). Evolutionary biologist Alan Templeton (2013) argues that while "Much of the recent scientific literature on human evolution portrays human populations as separate branches on an evolutionary tree," multiple lines of evidence falsify a phylogenetic tree structure, and confirm the presence of gene flow among populations. Jonathan Marks (2008) argues that Andreasen has misinterpreted the genetic literature: "These trees are phenetic (based on similarity), rather than cladistic (based on monophyletic descent, that is from a series of unique ancestors)." Marks, Templeton, and Cavalli-Sforza all conclude that genetics does not provide evidence of human races.

Anthropologists Lieberman and Jackson (1995) also critique the use of cladistics to support concepts of race. They claim that "the molecular and biochemical proponents of this model explicitly use racial categories *in their initial grouping of samples*". For example, the large and highly diverse macroethnic groups of East Indians, North Africans, and Europeans are presumptively grouped as Caucasians prior to the analysis of their DNA variation. This is claimed to limit and skew interpretations, obscure other lineage relationships, deemphasize the impact of more immediate clinal environmental factors on genomic diversity, and can cloud our understanding of the true patterns of affinity. They suggest that the authors of these studies find support for racial distinctions only because they began by assuming the validity of race. "For empirical reasons we prefer to place emphasis on clinal variation, which recognizes the existence of adaptive human hereditary variation and simultaneously stresses that such variation is not found in packages that can be labeled *races*."

Human population groups are not monophyletic, as there appears to always have been considerable gene flow between human populations. Keith Hunley, Graciela Cabana, and Jeffrey Long analyzed the Human Genome Diversity Project sample of 1,037 individuals in 52 populations. They found that non-African populations are a taxonomic subgroup of African populations, that "some African populations are equally related to other African populations and to non-African populations," and that "outside of Africa, regional groupings of populations are nested inside one another, and many of them are not monophyletic." Rachel Caspari (2003) has argued that since no groups currently regarded as races are monophyletic, none of those groups can be clades.

Morphologically differentiated populations

Population geneticists have debated whether the concept of *population* can provide a basis for a new conception of race. To do this, a working definition of population must be found. Surprisingly, there is no generally accepted concept of population that biologists use. Although the concept of population is central to ecology, evolutionary biology and conservation biology, most definitions of population rely on qualitative descriptions such as "a group of organisms of the same species occupying a particular space at a particular time". Waples and Gaggiotti identify two broad types of definitions for populations; those that fall into an *ecological paradigm*, and those that fall into an *evolutionary paradigm*. Examples of such definitions are:

- *Ecological paradigm*: A group of individuals of the same species that co-occur in space and time and have an opportunity to interact with each other.
- *Evolutionary paradigm*: A group of individuals of the same species living in close-enough proximity that any member of the group can potentially mate with any other member.

Sesardic argues that when several traits are analyzed at the same time, forensic anthropologists can classify a person's race with an accuracy of close to 100% based on only skeletal remains. Sesardic's claim has been disputed by Massimo Pigliucci, who accused Sesardic of "cherry pick[ing] the scientific evidence and reach[ing] conclusions that are contradicted by it." Specifically, Pigliucci argues that Sesardic misrepresented a paper by Ousley et al. (2009), and neglected to mention that they identified differentiation not just between individuals from different races, but also between individuals from different tribes, local environments, and time periods. This is discussed in a later section.

Clines

One crucial innovation in reconceptualizing genotypic and phenotypic variation was the anthropologist C. Loring Brace's observation that such variations, insofar as it is affected by natural selection, slow migration, or genetic drift, are distributed along geographic gradations or clines. For example, with respect to skin color in Europe and Africa, Brace writes:

To this day, skin color grades by imperceptible means from Europe southward around the eastern end of the Mediterranean and up the Nile into Africa. From one end of this range to the other, there is no hint of a skin color boundary, and yet the spectrum runs from the lightest in the world at the northern edge to as dark as it is possible for humans to be at the equator.

In part this is due to isolation by distance. This point called attention to a problem common to phenotype-based descriptions of races (for example, those based on hair texture and skin color): they ignore a host of other similarities and differences (for example, blood type) that do not correlate highly with the markers for race. Thus, anthropologist Frank Livingstone's conclusion, that since clines cross racial boundaries, "there are no races, only clines".

In a response to Livingstone, Theodore Dobzhansky argued that when talking about race one must be attentive to how the term is being used: "I agree with Dr. Livingstone that if races have to be 'discrete units', then there are no races, and if 'race' is used as an 'explanation' of the human variability, rather than vice versa, then the explanation is invalid." He further argued that one could use the term race if one distinguished between "race differences" and "the race concept". The former refers to any distinction in gene frequencies between populations; the latter is "a matter of judgment". He further observed that even when there is clinal variation, "Race differences are objectively ascertainable biological phenomena ... but it does not follow that racially distinct populations must be given racial (or subspecific) labels." In short, Livingstone and Dobzhansky agree that there are genetic differences among human beings; they also agree that the use of the race concept to classify people, and how the race concept is used, is a matter of social convention. They differ on whether the race concept remains a meaningful and useful social convention.

In 1964, the biologists Paul Ehrlich and Holm pointed out cases where two or more clines are distributed discordantly – for example, melanin is distributed in a decreasing pattern from the equator north and south; frequencies for the haplotype for beta-S hemoglobin, on the other hand, radiate out of specific geographical points in Africa. As the anthropologists Leonard Lieberman and Fatimah Linda Jackson observed, "Discordant patterns of heterogeneity falsify any description of a population as if it were genotypically or even phenotypically homogeneous".

Patterns such as those seen in human physical and genetic variation as described above, have led to the consequence that the number and geographic location of any described races is highly dependent on the importance attributed to, and quantity of, the traits considered. Scientists discovered a skin-lighting mutation that partially accounts for the appearance of Light skin in humans (people who migrated out of Africa northward into what is now Europe) which they estimate occurred 20,000 to 50,000 years ago. The East Asians owe their relatively light skin to different mutations. On the other hand, the greater the number of traits (or alleles) considered, the more subdivisions of humanity are detected, since traits and gene frequencies do not always correspond to the same geographical location. Or as Ossorio & Duster (2005) put it:

Anthropologists long ago discovered that humans' physical traits vary gradually, with groups that are close geographic neighbors being more similar than groups that are geographically separated. This pattern of variation, known as clinal variation, is also observed for many alleles that vary from one human group to another. Another observation is that traits or alleles that vary from one group to another do not vary at the same rate. This pattern is referred to as nonconcordant variation. Because the variation of physical traits is clinal and nonconcordant, anthropologists of the late 19th and early 20th centuries discovered that the more traits and the more human groups they measured, the fewer discrete differences they observed among races and the more categories they had to create to classify human beings. The number of races observed expanded to the 1930s and 1950s, and eventually anthropologists concluded that there were no discrete races. Twentieth and 21st century biomedical researchers have discovered this same feature when evaluating human variation at the level of alleles and allele frequencies. Nature has not created four or five distinct, nonoverlapping genetic groups of people.

Genetically differentiated populations

Another way to look at differences between populations is to measure genetic differences rather than physical differences between groups. The mid-20th-century anthropologist William C. Boyd defined race as: "A population which differs significantly from other populations in regard to the frequency of one or more of the genes it possesses. It is an arbitrary matter which, and how many, gene loci we choose to consider as a significant 'constellation'". Leonard Lieberman and Rodney Kirk have pointed out that "the paramount weakness of this statement is that if one gene can distinguish races then the number of races is as numerous as the number of human couples reproducing." Moreover, the anthropologist Stephen Molnar has suggested that the discordance of clines inevitably results in a multiplication of races that renders the concept itself useless. The Human Genome Project states "People who have lived in the same geographic region for many generations may have some alleles in common, but no allele will be found in all members of one population and in no members of any other." Massimo Pigliucci and Jonathan Kaplan argue that human races do exist, and that they correspond to the genetic classification of ecotypes, but that real human races do not correspond very much, if at all, to folk racial categories. In contrast, Walsh & Yun reviewed the literature in 2011 and reported that "Genetic studies using very few chromosomal loci find that genetic polymorphisms divide human populations into clusters with almost 100 percent accuracy and that they correspond to the traditional anthropological categories."

Some biologists argue that racial categories correlate with biological traits (e.g. phenotype), and that certain genetic markers have varying frequencies among human populations, some of which correspond more or less to traditional racial groupings. For this reason, there is no current consensus about whether racial categories can be considered to have significance for understanding human genetic variation.

Distribution of genetic variation

The distribution of genetic variants within and among human populations are impossible to describe succinctly because of the difficulty of defining a population, the clinal nature of variation, and heterogeneity across the genome (Long and Kittles 2003). In general, however, an average of 85% of statistical genetic variation exists within local populations, ~7% is between local populations within the same continent, and ~8% of variation occurs between large groups living on different continents. The recent African origin theory for humans would predict that in Africa there exists a great deal more diversity than elsewhere and that diversity should decrease the further from Africa a population is sampled. Hence, the 85% average figure is misleading: Long and Kittles find that rather than 85% of human genetic diversity existing in all human populations, about 100% of human diversity exists in a single African population, whereas only about 60% of human genetic diversity exists in the least diverse population they analyzed (the Surui, a population derived from New Guinea). Statistical analysis that takes this difference into account confirms previous findings that, "Western-based racial classifications have no taxonomic significance."

Cluster analysis

A 2002 study of random biallelic genetic loci found little to no evidence that humans were divided into distinct biological groups.

In his 2003 paper, "Human Genetic Diversity: Lewontin's Fallacy", A. W. F. Edwards argued that rather than using a locus-by-locus analysis of variation to derive taxonomy, it is possible to construct a human classification system based on characteristic genetic patterns, or *clusters* inferred from multilocus genetic data. Geographically based human studies since have shown that such genetic clusters can be derived from analyzing of a large number of loci which can assort individuals sampled into groups analogous to traditional continental racial groups. Joanna Mountain and Neil Risch cautioned that while genetic clusters may one day be shown to correspond to phenotypic variations between groups, such assumptions were premature as the relationship between genes and complex traits remains poorly understood. However, Risch denied such limitations render the analysis useless: "Perhaps just using someone's actual birth year is not a very good way of measuring age. Does that mean we should throw it out? ... Any category you come up with is going to be imperfect, but that doesn't preclude you from using it or the fact that it has utility."

Early human genetic cluster analysis studies were conducted with samples taken from ancestral population groups living at extreme geographic distances from each other. It was thought that such large geographic distances would maximize the genetic variation between the groups sampled in the analysis, and thus maximize the probability of finding cluster patterns unique to each group. In light of the historically recent acceleration of human migration (and correspondingly, human gene flow) on a global scale, further studies were conducted to judge the degree to which genetic cluster analysis can pattern ancestrally identified groups as well as geographically separated groups. One such study looked at a large multiethnic population in the United States, and "detected only modest genetic differentiation between different current geographic locales within each race/ethnicity group. Thus, ancient geographic ancestry, which is highly correlated with self-identified race/ethnicity – as opposed to current residence – is the major determinant of genetic structure in the U.S. population." (Tang et al. (2005))

Witherspoon et al. (2007) have argued that even when individuals can be reliably assigned to specific population groups, it may still be possible for two randomly chosen individuals from different populations/clusters to be more similar to each other than to a randomly chosen member of their own cluster. They found that many thousands of genetic markers had to be used in order for the answer to the question "How often is a pair of individuals from one population genetically more dissimilar than two individuals chosen from two different populations?" to be "never". This assumed three population groups separated by large geographic ranges (European, African and East Asian). The entire world population is much more complex and studying an increasing number of groups would require an increasing number of markers for the same answer. The authors conclude that "caution should be used when using geographic or genetic ancestry to make inferences about individual phenotypes." Witherspoon, et al. concluded that, "The fact that, given enough genetic data, individuals can be correctly assigned to their populations of origin is compatible with the observation that most human genetic variation is found within populations, not between them. It is also compatible with our nding that, even when the most distinct populations are considered and hundreds of loci are used, individuals are frequently more similar to members of other populations than to members of their own population."

Anthropologists such as C. Loring Brace, the philosophers Jonathan Kaplan and Rasmus Winther, and the geneticist Joseph Graves, have argued that while there it is certainly possible to find biological and genetic variation that corresponds roughly to the groupings normally defined as "continental races", this is true for almost all geographically distinct populations. The cluster structure of the genetic data is therefore dependent on the initial hypotheses of the researcher and the populations sampled. When one samples continental groups, the clusters become continental; if one had chosen other sampling patterns, the clustering would be different. Weiss and Fullerton have noted that if one sampled only Icelanders, Mayans and Maoris, three distinct clusters would form and all other populations could be described as being clinally composed of admixtures of Maori, Icelandic and Mayan genetic materials. Kaplan and Winther therefore argue that, seen in this way, both Lewontin and Edwards are right in their arguments. They conclude that while racial groups are characterized by different allele frequencies, this does not mean that racial classification is a natural taxonomy of the human species, because multiple other genetic patterns can be found in human populations that crosscut racial distinctions. Moreover, the genomic data underdetermines whether one wishes to see subdivisions (i.e., splitters) or a continuum (i.e., lumpers). Under Kaplan and Winther's view, racial groupings are objective social constructions that have conventional biological reality only insofar as the categories are chosen and constructed for pragmatic scientific reasons. In earlier work, Winther had identified "diversity partitioning" and "clustering analysis" as two separate methodologies, with distinct questions, assumptions, and protocols. Each is also associated with opposing ontological consequences vis-a-vis the metaphysics of race. Philosopher Lisa Gannett has argued that biogeographical ancestry, a concept devised by Mark Shriver and Tony Frudakis, is not an objective measure of the biological aspects of race as Shriver and Frudakis claim it is. She argues that it is actually just a "local category shaped by the U.S. context of its production, especially the forensic aim of being able to predict the race or ethnicity of an unknown suspect based on DNA found at the crime scene."

Clines and clusters in genetic variation

Recent studies of human genetic clustering have included a debate over how genetic variation is organized, with clusters and clines as the main possible orderings. Serre & Pääbo (2004) argued for smooth, clinal genetic variation in ancestral populations even in regions previously considered racially homogeneous, with the apparent gaps turning out to be artifacts of sampling techniques. Rosenberg et al. (2005) disputed this and offered an analysis of the Human Genetic Diversity Panel showing that there were small discontinuities in the smooth genetic variation for ancestral populations at the location of geographic barriers such as the Sahara, the Oceans, and the Himalayas. Nonetheless, Rosenberg et al. (2005) stated that their findings "should not be taken as evidence of our support of any particular concept of biological race... Genetic differences among human populations derive mainly from gradations in allele frequencies rather than from distinctive 'diagnostic' genotypes." Using a sample of 40 populations distributed roughly evenly across the Earth's land surface, Xing

& et. al. (2010, p. 208) found that "genetic diversity is distributed in a more clinal pattern when more geographically intermediate populations are sampled."

Guido Barbujani has written that human genetic variation is generally distributed continuously in gradients across much of Earth, and that there is no evidence that genetic boundaries between human populations exist as would be necessary for human races to exist.

Over time, human genetic variation has formed a nested structure that is inconsistent with the concept of races that have evolved independently of one another.

Social constructions

As anthropologists and other evolutionary scientists have shifted away from the language of race to the term *population* to talk about genetic differences, historians, cultural anthropologists and other social scientists re-conceptualized the term "race" as a cultural category or social construct, i.e., a way among many possible ways in which a society chooses to divide its members into categories.

Many social scientists have replaced the word race with the word "ethnicity" to refer to self-identifying groups based on beliefs concerning shared culture, ancestry and history. Alongside empirical and conceptual problems with "race", following the Second World War, evolutionary and social scientists were acutely aware of how beliefs about race had been used to justify discrimination, apartheid, slavery, and genocide. This questioning gained momentum in the 1960s during the civil rights movement in the United States and the emergence of numerous anti-colonial movements worldwide. They thus came to believe that race itself is a social construct, a concept that was believed to correspond to an objective reality but which was believed in because of its social functions.

Craig Venter and Francis Collins of the National Institute of Health jointly made the announcement of the mapping of the human genome in 2000. Upon examining the data from the genome mapping, Venter realized that although the genetic variation within the human species is on the order of 1–3% (instead of the previously assumed 1%), the types of variations do not support notion of genetically defined races. Venter said, "Race is a social concept. It's not a scientific one. There are no bright lines (that would stand out), if we could compare all the sequenced genomes of everyone on the planet." "When we try to apply science to try to sort out these social differences, it all falls apart."

Stephan Palmié asserted that race "is not a thing but a social relation"; or, in the words of Katya Gibel Mevorach, "a metonym", "a human invention whose criteria for differentiation are neither universal nor fixed but have always been used to manage difference." As such, the use of the term "race" itself must be analyzed. Moreover, they argue that biology will not explain why or how people use the idea of race: History and social relationships will.

Imani Perry has argued that race "is produced by social arrangements and political decision making." Perry explains race more in stating, "race is something that happens, rather than something that is. It is dynamic, but it holds no objective truth."

Some scholars have challenged the notion that race is primarily a social construction by arguing that race has a biological basis. One of the researchers, Neil Risch, noted: "we looked at the correlation between genetic structure [based on microsatellite markers] versus self-description, we found 99.9% concordance between the two. We actually had a higher discordance rate between self-reported sex and markers on the X chromosome! So you could argue that sex is also a problematic category. And there are differences between sex and gender; self-identification may not be correlated with biology perfectly. And there is sexism."

European Union

According to the Council of the European Union:

The European Union rejects theories which attempt to determine the existence of separate human races. —*Directive 2000/43/EC*

The European Union uses the terms racial origin and ethnic origin synonymously in its documents and according to it "the use of the term 'racial origin' in this directive does not imply an acceptance of such [racial] theories". Haney López warns that using "race" as a category within the law tends to legitimize its existence in the popular imagination. In the diverse geographic context of Europe, ethnicity and ethnic origin are arguably more resonant and are less encumbered by the ideological baggage associated with "race". In European context, historical resonance of "race" underscores its problematic nature. In some states, it is strongly associated with laws promulgated by the Nazi and Fascist governments in Europe during the 1930s and 1940s. Indeed, in 1996, the European Parliament adopted a resolution stating that "the term should therefore be avoided in all official texts".

The concept of racial origin relies on the notion that human beings can be separated into biologically distinct "races", an idea generally rejected by the scientific community. Since all human beings belong to the same species, the ECRI (European Commission against Racism and Intolerance) rejects theories based on the existence of different "races". However, in its Recommendation ECRI uses this term in order to ensure that those persons who are generally and erroneously perceived as belonging to "another race" are not excluded from the protection provided for by the legislation. The law claims to reject the existence of "race", yet penalize situations where someone is treated less favourably on this ground.

United States

In the United States, there is disagreement on the nature of race within the biological sciences, whereas the social constructionist view is dominant in the social sciences; over time, biological views on race have become more controversial across all disciplines, with clear divides along generational, cultural, and racial lines.

The immigrants to the Americas came from every region of Europe, Africa, and Asia. They mixed among themselves and with the indigenous inhabitants of the continent. In the United States most people who self-identify as African–American have some European ancestors, while many people who identify as European American have some African or Amerindian ancestors.

Since the early history of the United States, Amerindians, African–Americans, and European Americans have been classified as belonging to different races. Efforts to track mixing between groups led to a proliferation of categories, such as mulatto and octoroon. The criteria for membership in these races diverged in the late 19th century. During Reconstruction, increasing numbers of Americans began to consider anyone with "one drop" of known "Black blood" to be Black, regardless of appearance. By the early 20th century, this notion was made statutory in many states. Amerindians continue to be defined by a certain percentage of "Indian blood" (called *blood quantum*). To be White one had to have perceived "pure" White ancestry. The one-drop rule or hypodescent rule refers to the convention of defining a person as racially black if he or she has any known African ancestry. This rule meant that those that were mixed race but with some discernible African ancestry were defined as black. The one-drop rule is specific to not only those with African ancestry but to the United States, making it a particularly African-American experience.

The decennial censuses conducted since 1790 in the United States created an incentive to establish racial categories and fit people into these categories.

The term "Hispanic" as an ethnonym emerged in the 20th century with the rise of migration of laborers from the Spanish-speaking countries of Latin America to the United States. Today, the word "Latino" is often used as a synonym for "Hispanic". The definitions of both terms are non-race specific, and include people who consider themselves to be of distinct races (Black, White, Amerindian, Asian, and mixed groups). However, there is a common misconception in the US that Hispanic/Latino is a race or sometimes even that national origins such as Mexican, Cuban, Colombian, Salvadoran, etc. are races. In contrast to "Latino" or "Hispanic", "Anglo" refers to non-Hispanic White Americans or non-Hispanic European Americans, most of whom speak the English language but are not necessarily of English descent.

THE RACES OF MANKIND

Race has been defined as "a biological grouping within the human species, distinguished or classified according to genetically transmitted differences". The race as an expression has been used in different context, viz. culture, tradition, language and nationality. These are not scientific criteria, since they are neither biological nor inherited.

There has been some difference of opinion regarding the origin of different races. One school of thought argues that racial differences existed from the very beginning, while another school of thought believes that different r\aces developed from one single ancestral species.

The scientific classification of human racial types is based on certain combinations of fixed, inherited, as far as possible measurable and visually identifiable traits, such as head shape, eye shape and colour, skin colour, stature, blood groups etc. These traits represent morphological, biological and genetical aspects. With the inclusion of more and more traits, the number of combinations increases and the analysis becomes more complex.

There is no single way of classifying mankind into biological races. In the past, physical characteristics, such as skin colour and hair type, were used to delineate three to five biological races (Caucasoid, Negroid and Mongoloid and later, Austrloid and American Indian). More subtle techniques, taking into account blood types and hereditary diseases well as terrain barriers, result in classifications that may include as many as eight or nine geographical race. Although difference of opinion exists regarding terminology and the exact classification, the following divisions are generally accepted:

- Caucasoid (Eruopean)

- Negrodi (Afican)
- Mongoloid (Asistic or Oriental)
- Indic (Hindu)
- Australoid (Australian aboriginals)
- Polynesians/Melanesioan/Micronesian (sometimes, these three are classified as the Oceanic)

Generally speaking, the spatial distribution and concentration of these races is Caucasoids in Europe, Mongoloids in Asia and Negroids in Africa. But these races are not limited, in spatial extent, to these areas only. For instance, the Caucasoid race is also found along the northern belt of Africa, Turkey and from Iran to Baluchistan and India. The Mongoloid race is mainly found in the central, eastern and south-eastern parts of Asia and the western parts of the Americas (Red Indians etc.), Arctic region (Eskimos in Canada, Greenland and Yakuts in Siberia). In other worlds, the Mongoloids are clustering around the Pacific and the Arctic Oceans. The Negroids are mainly concentrated in the south of Sahara desert in Africa, but they are also found in Indonesia (pygmy group), Papua New Guinea and Melanesia. The Australoids, a mixture of Negroids and Dravidians (south India), are largely concentrated in Australia, especially in the north and west.

CLASSIFICATION OF RACES IN MANKIND

The classification of mankind into a number of permanent varieties or races, rests on grounds which are within limits not only obvious but definite. Whether from a popular or a scientific point of view, it would be admitted that a Negro, a Chinese, and an Australia, belong to three such permanent varieties of men, all plainly distinguishable from one another and from any European. Moreover, such a division takes for granted the idea which is involved in the word race, that each of these varieties is due to special ancestry, each race thus representing an ancient breed or stock, however these breeds or stocks may have had their origin.

The anthropological classification of mankind is thus zoological in its nature, like that of the varieties or species of any other animal group, an the character on which it is based on in great measure physical, though intellectual and traditional peculiarities, such as moral habit and language, furnish important aid. Among the best-marked racecharacters are the following:—The colour of the skin has always been held as specially distinctive.

The coloured race-portraits of ancient Egypt remain to prove the permanence of complexion during a lapse of a hundred generations, distinguishing coarsely but clearly the types of the red-brown Egyptian, the yellow-brown Canaanite, the comparatively fair Libyan, and the Negro These broad distinctions have the same kind of value as the popular terms describing white, yellow, brown, and black races, which often occur in ancient writings, and are still used. But for scientific purposes greater accuracy is required, and this is now satisfactorily attained by the use of Dr. Broca's graduated series of colours as a standard (Memoires de la Societe d'Anthropologie de Paris, ii.) By this, the varieties of the human skin may be followed from the fairest hue of the Swede and the darker tint of the Provencal, to the withered-leaf brown of the Hottentot, the chocolate brown of the Mexican, and the brown-black of the West African. The colour of the eyes and hair is also to be defined accurately by Broca's table.

This affords, however, less means of distinction, from the extent in which dark tints of hair and iris are common to races whose skins are more perceptibly different; yet some varieties are characteristic, such as the blue eyes and flaxen hair of that fair race of Northern Europe. As to the hair, its structure and arrangement is a better indication of race than its tint. The fair differs in quantity between scantiness of the body of the Mongol and profusion on the body of the Aino; while as to the arrangement on the scalp, the tufts of the Bushman contrast with the more equal distribution on the European head. The straight hair of the North American or Malay is recognizable at once as different from the waving or curling hair of the European, and both from the naturally frizzed hair of the Negro.

These marked differences are due to the structure of the hair, wick, examined in sections under the microscope, varies from the circular section proper to the straight-haired races, to the more or less symmetrically oval or reniform sections belonging to races with curled and twisted hair. Stature is by no means a general criterion of race, and it would not, for instance, be difficult to choose groups of Englishmen, Kafirs, and North American Indians, whose mean height should hardly differ. Yet in many cases it is a valuable means of distinction, as between the tall Patagonians and the stunted Fuegians, and even as a help in minuter problems, such as separating the Teutonic and Keltic ancestry in the population of England. Proportions of the limbs, compared in length with the trunk, have been claimed as constituting peculiarities of African and American races; and other anatomical points, such as the conformation of the pelvis, have speciality.

But inferences of this class have hardly attained to sufficient certainty and generality to be set down in the form of rules. The conformation of the skull is second only to the colour of the skin as a criterion for the distinction of race. The principal modes of estimating the differences of skulls are the following: - The skull being seen from above, the proportions of the two diameters are estimated on the principle employed by Retzius: taking the longer diameter from front to back as 100, if the shorter or cross diameter falls below 80, the skull may be classed as long (dolichocephalic; while if it exceeds 80, the skull may be classed as broad (brachycephalic); or a third division may be introduced between these as intermediate (mesocephalic), comprehending skulls with a proportionate breadth of 75 to 80, or thereabout. The percentage of breadth to length measured in this manner is known as the cephalic index; thus, the cephalic index of a Negro or Australian may be as low as 72, and that of a Tatar as high as 88, while the majority of Europeans have an index not departing in either direction very far from 78. The cephalic height is measured in the same way as a percentage of the length.

The back view (norma occipitalis) of the skull is distinguished as rounded, pentagonic, &c., and the base view of the skull shows the position of the occipital foramen and the zygomatic arches. The position of the jaws is recognized as important, races being described as prognathous when the jaws project, far, as in the Asutralian or Negro, in contradistinction to the orthognathous type, which is that of the ordinary well-shaped European skull. On this distinction in great measure depends the celebrated "facial angle," measured by Camper as a test of low and high races; but this angle is objectionable as resulting partly from the development of the forehead and partly from the position of the jaws. The capacity of the cranium is estimated in cubic measure by filling it with sand, &c., with the general result that the civilized white man is found to have a larger brain than the barbarian or savage.

Classification of races on cranial measurements has long been attempted by eminent anatomists, such as Blumenbach and Retzius, while the later labours of Von Baer, Welcker, Davis, Broca, Busk, Lucae, and many others, have brought the distinctions to extreme minuteness. In certain cases great reliance may be placed on such measurements. Thus the skulls of an Asutralian and a Negro would be generally distinguished by their narrowness and the projection of the jaw from that of any Englishman; while, although both the Australian and Negro are thus dolichocephalic and prognathous, the first would usually differ perceptibly from the second in its upright sides and strong orbital ridges. The relation of height to breadth may furnish a valuable test; thus both the Hafir and the Bushman are dolichocephalic, with an index of about 72, but they differ in the index of height, which may be 73 and 71 respectively, in the one case more than the width and in the other less.

It is, however, acknowledged by all experienced craniologists, that the shape of the skull may vary so much within the same tribe, and even the same family, that it must be used with extreme caution, and if possible only in conjunction with other criteria of race. The general contour of the face, in part dependent on the form of the skull, varies much in different races, among whom it is loosely defined as oval, lozenge-shaped, pentagonal, &c. Of particular features, some of the most marked contrast to European types are seen in the oblique Chinese eyes, the broad-set Kamchadal cheeks, the pointed Arab chin, the snub Kirghis nose, the fleshy protuberant Negro lips, and the broad Kalmuk ear. Taken altogether, the features have a typical character which popular observation seizes with some degree of correctness, as in the recognition of the Jewish countenance in a European city. The state of adaptation in which each people stands to its native climate forms a definite race-character. In its extreme form this is instanced in the harmful effect of the climate of India on children of European parents, and the corresponding danger in transporting natives of tropical climates to England. Typical instances of the relation of race-constitutions to particular diseases are seen in the liability of Europeans in the West Indies to yellow fever, from which Negroes are exempt, and in the habitation by tribes in India of so-called "unhealthy districts," whose climate is deadly to Europeans, and even to natives of neighbouruing regions. Even the vermin infesting different races of men are classified by Mr. A. Murray as distinct. The physical capabilities of different races are known to differ widely, but it is not easy to discriminate here between hereditary race-differences and those due to particular food and habit of life.

A similar difficulty has hitherto stood in the way of any definite classification of the emotional, moral and intellectual characters of races. Some of the most confident judgment which have been delivered on this subject have been dictated by prejudice or willful slander, as in the many lamentable cases in which slave-holders and conquerors have excused their ill-treatment of subject and invaded races on the ground of their being creatures of bestial nature in mind and morals. Two of the best-marked contrasts of mental type recorded among races are Mr. A. R. Wallace's distinction between the sky, reserved, and impassive Malay and the sociable and demonstrative Papuan (Tr. Eth. Soc., vol. iii. p. 200), and the very similar difference pointed out by Spix and Martius between the dull and morose natives of the Brazilian forests, an the lively sensuous African Negroes brought into contact with them (Riese in Brasilien, vol. I).

In general, however, descriptions of national or racial character are so vitiated by the confusion of peculiarity of natural character with stage of civilization, that they can only be made use of with the greatest reserve. Every division of mankind presents in every character wide deviations from a standard. Thus the Negro race, well marked as it may seem at the first glance, proves on closer examination to include several shades of complexion and features, in some districts varying far from the accepted Negro type; while the examination of a series of native American tribes shows that, notwithstanding their asserted uniformity of type, they differ in stature, colour, features, and proportions of skull.

Detailed anthropological research, indeed, more and more justifies Blumenbach's words, that "innumerable varieties of mankind run into one another by insensible degrees." This state of things, due partly to mixture and crossing of races, and partly to independent variation of types, makes the attempt to arrange the whole human species within exactly bounded divisions an apparently hopeless task. It does not follow, however, that the attempt to distinguish special races should be given up, for there at least exist several definable types, each of which so far prevails in a certain population as to be taken as its standard. M. Quetelet's plan of defining such types will probably meet with general acceptance as the scientific method proper to this branch of anthropology. It consists in the determination of the standard, or typical "mean man" (homme moyen) of a population, with reference to any particular quality, such as stature, weight, complexion, &c.

In the case of statute, this would be done by measuring a sufficient number of men, and accounting how many of them belong to each height on the scale. If it be thus ascertained, as it might be in an English district, that the 5 ft. 7 in. men form the most numerous group, while the 5 ft. 6 in. and 5 ft. 8 in. men are less in number, and the 5 ft. 5 in. and 5 ft. 9 in. still fewer, and so on until the extremely small number of extremely short or tall individuals of 5 ft. or 7 ft. is reached, it will thus be ascertained that the stature of the mean or typical man is to be taken as 5 ft. 7 in. The method is thus that of selecting as the standard the most numerous group, on both sides of which the groups decrease in number as they vary in type.

Such classification may show the existence of two or more types in a community, as, for instance, the population of a Californian settlement made up of Whites and Chinese might show two predominant groups (one of 5 ft. 8 in., the other of 5 ft. 4 in) corresponding to these two racial types. It need hardly be said that this method of determining the mean type of a race, as being that of its really existing and mist numerous class, is altogether superior to the ere calculation of an average, which may actually be represented by comparatively few individuals, and those the exceptional ones.

For instance, the average stature of the mixed European and Chinese population just referred to might be 5 ft. 6 in — a worthless and, indeed, misleading result. The measurement and description of the various races of men are now carried to great minuteness so that race classification is rapidly improving as to both scope and accuracy. Even where comparatively loose observations have been made, it is possible, by inspection of considerable number of individuals, to define the prevalent type of a race with tolerable approximation to the real mean or standard man. It is in this way that the subdivision of mankind into races, so far as it has been done to any purpose, has been carried out by anthropologists.

These classifications have been numerous, and though, regarded as system,s most of them are now seen at the first glance to be unsatisfactory, yet they have been of great value in systematizing knowledge, and are all more or less based on indisputable distinctions. Blumenbach's division, though published nearly a century ago (1781), has had the greatest influence. He reckon five races, *viz.*, Caucasian, Mongolian, Ethiopian, American, Malay. The ill-chosen name of Caucasian, used by Blumenbach to denote what may be called white men, is still current; it brings into one race peoples such as the Arabs and Swedes, although these are scarcely less different than the Americans and Malays, who are set down as two distinct races.

Again, two of the best-marked varieties of mankind are the Australians and the Bushmen, neither of whom, however, seem to have a natural place in Blumebach's series. The yet simpler classification by Cuvier into Caucasian, Mongol, and Negro, corresponds in some measure with a division by mere complexion into white, yellow, and black races; but neither this threefold division, nor the ancient classification into Semitic, Hamitic, and Japhetic nations can be regarded as separating the human types either justly or sufficiently. Schemes which set up a larger number of distinct races, such as the eleven of Pickering, the fifteen of Bory de St Vincent, and the sixteen of Desmoulins, have the advantage of finding niches for most well-defined human varieties; but no modern naturalist would be likely to adopt any one of these as it stands. In criticism of Pickering's system, it is sufficient to point out that he divides the white nations into two races, entitled the Arab and the Abyssinian. Agassiz, Nott, Crawfurd, and others who have assumed a much larger number of races or species of man, are not considered to have satisfactorily defined a corresponding number of distinguishable types.

On the whole, Professor Huxley's recent scheme probably approaches more nearly than any other to such a tentative classification as may be accepted in definition of the principal varieties of mankind, regarded from a zoological point of view, though anthropologists may be disposed to erect into separate races several of his widely-differing sub-races. He ditinsguishes four principal types of mankind, the Australioid, Negroid, Mongoloid, and Xanthochoroic, adding a fifth variety, the Melanochroic.

The special points of the Australioid are a chocolate-brown skin, dark brown or black eyes, black hair (usually wavy), narrow (dolichocephalic) skull, brow-ridges strongly developed, projecting jaw, coarse lips, and broad nose. This type is best represented by the natives of Australia, and next to them, by the indigenous tribes of Southern India, the so-called coolies. The Egyptians to some degree approach this type; they are, however, held by good authorities to be a modified African race.

The Negroid type is primarily represented by the Negro of Africa, between the Sahara and the Cape district, including Madagascar. The skin varies from dark brown to brown-black, with eyes of similar dark hue, and hair usually black, and always crisp or woolly. The skull is narrow (dolichocephalism), with orbital ridges not prominent, prognathous, with depressed nasal, bones, causing the nose to be flat as well as broad; and the lips are coarse and projecting.

Two important families are classed in this system as special modifications of the Negroid type. First, the Bushman of South Africa is diminutive in stature, and of yellowish-brown complexion; the Hottentot is supposed to be the result of crossing between the Bushman and ordinary Negroid.

Second, the Negritos of the Andaman Islands, the peninsula of Malacca, the Philippines and other islands, to New Caledonia and Tasmania, are mostly dolichocephalism, with dark skins and woolly hair. In various districts they tend towards other types, and show traces of mixture.

The Mongoloid type prevails over the vast area lying east of a line drawn from Lapland to Siam. Its definition includes a short, squat build, a yellowish brown complexion, with black eyes and black straight hair, a broad (brachycephalic) skull, usually without prominent brow-ridges, flat small nose, and oblique eyes.

The dolichocephalic Chinese and Japanese in other respect correspond. Various other important branches of the human species are brought into connection with the Mongoloid type, though on this view the differences they present raise difficult problems of gradual variations, as well as of mixture of race; these are the Dyak-Malays, the Polynesians, and the Americans.

The Xanthochroi, or fair whites-tall, with almost colourless skin, blue or grey eyes, hair from straw colour to chesnut, and skulls varying as to proportionate width- are the prevalent inhabitants of Northern Europe, and the type may be traced into North Africa, and eastward as far as Hindostan.

On the south and west it mixes with that of the Melanochroi, or dark whites, and on the north and east with that of the Mongoloids. The Melanochroi, or dark whites, differ from the fair whites in the darkening of the complexion to brownish and olive, and of the eyes and hair to black, while the stature is somewhat lower and the frame lighter. To this class belong a large part of those classed as Kelts, and of the populations of Southern Europe, such as Spaniards, Greeks, and Arabs, extending as far as India; while endless intermediate grades between the two white types testify to ages of intermingling.

Professor Huxley is disposed to account for the Melanochroi as themselves the result of crossing between the Xanthochroi and the Australioids. Whatever ground there may be for his view, it is obviously desirable to place them in a class by themselves, distinguishing them by an appropriate name

In determining whether the races of mankind are to be classed as varieties of one species, it is important to decide whether every two races can unite to produce fertile offspring. It is settled by experience that the most numerous and well-known crossed races, such as the Mulattos, descended from Europeans and Negroes-the Mestizos, from Europeans and American indigenes — the Zambos, from these American indigenes and Negroes, &c., are permanently fertile.

They practically constitute sub-races, with a general blending of the characters of the two parents, and only differing from fully established races in more or less tendency to revert to one or other of the original types. It has been argued, on the other hand, that not all such mixed breeds are permanent, and especially that the cross between European and Australian indigenes is almost sterile; but this assertion, when examined with the care demanded by its bearing on the general question of hybridity, has distinctly broken down. On the whole, the general evidence favours the opinion that any two races may combine to produce a new sub-race, which again may combine with any other variety.

Thus, if the existence of a small number of distinct races of mankind be taken as a starting-point, it is obvious that their crossing would produce an indefinite number of secondary varieties, such as the population of the world actually presents. The working out in detail of the problem, how far the differences among complex, nations, such as those of Europe, may have been brought about by hybridity, is still, however, a task of almost hopeless intricacy. Among the boldest attempts to account for distinctly-marked population as resulting from the intermixture of two races, are Professor Huxley's view that the Hottentots are hybrid between the Bushmen and the Negroes, and his more important suggestion, that the Melnochroic peoples of Southern Europe are of mixed Xanthochoric and Australioid stock.

The problem of ascertaining how the small number of races, distinct enough to be called primary, can have assumed their different types, has been for years the most disputed field of anthropology, the battle-ground of the rival schools of monogenists and polygenists. The one has claimed all mankind to be descended from one original stock, and generally from a single pair; the other has contended for the several primary races being separate species of independent origin. It is not merely as a question of natural history that the matter has been argued. Biblical authority has been appealed to, mostly on the side of the monogenists, as recording the descent of mankind from a single pair. On the other hand, however, the polygenists not less confidently claim passages from which they infer the existence of non-Adamite, as well as Adamite races of man. Nor have political considerations been without influence, as where, for instance, one American school of ethnologists have been thought to have formed, under the bias of a social system recognizing slavery, their opinion that the Negro and the white man are of different species. Of the older school of scientific monogenists, Blumenbach and Prichard are eminent representatives, as is Quatrefages of the more modern. The great problem of the monogenist theory is to explain by what course of variation the so different races of man have arisen from a single stock.

In ancient times little difficulty was left in this, authorities such as Aristotle and Vitruvius seeing in climate and circumstance the natural cause of racial differences, the Ethiopian having been blackened by the tropical sun, &c. Later and closer observations, however, have shown such influences to be, at any rate, far slighter in amount and slower in operation than was once supposed. M.

de Quatrefages brings forward (Unite de l'Espece Humanine, Paris, 1861, ch. 13) his strongest arguments for the variability of races under change of climate, &c (action du milieu), instancing the asserted alteration in complexion, constitution, and character of Negroes in America, and Englishmen in America and Australia. But although the reality of some such modification is not disputed, especially as to stature and constitution, its amount is not enough to upset the counter-proposition of the remarkable permanence of type displayed by races ages after they have been transported to climates extremely different from that of their former home.

Moreover, physically different races, such as the Bushmen and Negroids in Africa, show no signs of approximation under the influence of the same climate; while on the other hand, the coast tribes of Tierra del Fuego and forest tribes of tropical Brazil continue to resemble one another, in spite of extreme differences of climate and food. Mr. Darwin, than whom no naturalist could be more competent to appraise the variation of a species, is moderate in his estimation of the changes produced on races of man by climate and mode of life within the range of history.

The slightness and slowness of variation in human races having become known, a great difficulty of the monogenist theory was seen to lie in the shortness of the chromology with which it was formerly associated. Inasmuch as several well-marked races of mankind, such as the Egyptian, Phoenician, Ethiopian, &c., were much the same three or four thousand years ago as now, their variation from a single stock in the course of any like period could hardly be accounted for without a miracle. This difficulty was escaped by the polygenist theory, which, till a few years since, was gaining ground. Two modern views have, however, intervened which have tended to restore, though under a new aspect, the doctrine of a single human stock.

One has been the recognition of man having existed during a vast period of time, which made it easier to assume to continuance of very slow natural variation as having differenced even the white man and the Negro among the descendants of a common progenitor. The other wise is that of the evolution or development of species, at the present day so strongly upheld among naturalists. It does not follow necessarily form a theory of evolution of species that mankind must have descended from a single stock, for the hypothesis of development admits of the arguments, that several simious species may have culminated in several races of man.

The general tendency of the development theory, however, is against constituting separate species where the differences are moderate enough to be accounted for a due to variation from a single type. Mr. Darwin's summing up of the evidence as to unity of type throughout the races of mankind is as distinctly a monogenist argument as those of Blumenbach, Prichard or Quatrefages- "Although the existing races of man differ in many respects, as in colour, hair, shape of skull, proportions of the body, &c., yet, if their whole organization be take into consideration, they are found to resemble each other closely in a multitude of points. Many of these points are of so unimportant, or of so singular a nature, that it is extremely improbable that they should have been independently acquired by aboriginally distinct species or races.

The same remark holds good with equal or greater force with respect to the numerous points of mental similarity between the most distinct races of man... Now, when naturalists observe a close agreement in numerous small details of habits, tastes, and dispositions between two or more domestic races, or between nearly allied natural forms, they use this fact as an argument that all are descended from a common progenitor, who was thus endowed; and consequently, that all should be classed under the same species.

The same argument may be applied with much force to the races of man." A suggestion by Mr. A.R. Wallace has great importance in the application of the development theory to the origin of the various races of man; it is aimed to meet the main difficulty of the monogenist school, how races which have remained comparatively fixed in type during the long period of history, such as the white man and the Negro, should have, in even a far longer period, passed by variation from a common original.

Mr. Wallace's view is substantially that the remotely ancient representatives of the human species, being as yet animals too low in mind to have developed those arts of maintenance and social ordinances by which man holds his own against influences from climate and circumstance, were in their then wild state much more plastic than now to external nature; so that "natural selection" and other causes met with but feeble resistance in forming the permanent varieties or races of man, whose complexion and structure still remain fixed in their descendants.

On the whole, it may be asserted that the doctrine of the unity of mankind now stands on a firmer basis than in previous ages. It would be premature to judge how far the problem of the origin of races may be capable of exact solution; but the experience of the last few years countenances Mr. Darwin's prophecy, that before long the dispute between the monogenists and the polygenists will die a silent and unobserved death.

7

Agro Ecological Zones and Flora & Fauna

AGRO-ECOLOGICAL REGIONS OF INDIA – MEANING AND DETERMINING

Agro-ecology refers to the study of agricultural ecosystems and their components as they function in themselves and as a part of the larger ecosystem. Such a study would help in evolving more sustainable agricultural ecosystems. It is important to understand the difference between an agro-climatic zone and an agro-ecological zone.

Agro-climatic zone refers to a land unit in terms of its major climate, superimposed on the length of growing period or moisture availability period; agro-ecological zone is the land unit carved out of agro-climatic zone and superimposed on landform which influences both the climate and length of growing period.

So study of an agro-ecological zone will involve examining its climate, soil, water, flora and fauna. A systematic investigation of the agro-ecological regions, which would be somewhat homogeneous regions in terms of soil, climate and physiography and conducive moisture availability periods or length of growing period, is extremely important for planning appropriate land use.

India has landforms that can boast of a rare variety, in climatic conditions and soil types in particular. Its high mountains, deltas, dense forests, peninsular plateaus with varying temperatures—

from arctic cold to equatorial hot— and rainfall conditions—extreme aridity and a few centimetres of rainfall to perhumid and a maximum rainfall of even 1120 cm. A study of the country's agro-ecological regions is necessary for several reasons such as to determine yield potentialities of different crops, and crop combinations in the agro-ecological regions in the future.

It would help in deciding future action in terms of crop diversification. It would determine the best kind of crops to be grown in a piece of land keeping optimisation of land use requirements in mind. It aids in spread of knowledge of agricultural research and agro-technology.

Determining, Agro-Ecological Regions

How are agro-ecological regions (AERs) marked out and further sub-divided into agro-ecological sub-regions (AESRs). The basic criteria that decides the declination of the regions/subregions are aspects of soil physiography, length of growing period and bio-climate.

The agro-ecological regions of India have been differently classified by different experts based on these criteria. Murthy and Pandey (1978) classify the AERs into the following: Humid Western Himalayan Region, Humid Eastern Himalayan Region, Humid Bengal-Assam Basin; Sub-humid Sutlej-Ganga Alluvial Plains; Western Arid Plains; Sub-humid Eastern/Southern Uplands and Central Highlands; Semi-arid Lava Plateau, Humid to Semi-arid Western Ghats and Karnataka Plateau; and Bay Islands.

According to another classification (Sehgal et al, 1990), the AERs of India are: Western Himalayas—Cold Arid Region and Western Humid Region; Eastern Himalayas—Humid Region, Assam, Bengal and the North-eastern Hills; Northern Plains, Central Highlands; Western Plains and Kutch Peninsula, Kathiawar Peninsula; Deccan Plateau and Eastern Ghats, Chhotanagpur Plateau, East Coast Region; Western Ghats and Coastal Region; and Islands of Andaman and Nicobar and Lakshadweep.

India has been grouped into 20 AERs and these classified into 60 AESRs following this criteria by K.S. Gajbhiye and C. Mandal who are associated with the National Bureau of Soil Survey and Land Use Planning, Nagpur. Each AER is classified into agro-ecological unit at district level for developing long-term land use strategies.

ZONE DEFINITION

Zoning divides the area into smaller units based on distribution of soil, land surface and climate. The level of detail to which a zone is defined depends on the scale of the study, and sometimes on the power of the data processing facilities. The Kenya AEZ study (FAO, 1993a) distinguishes agro-ecological cells (AECs), which are the basic units for land evaluation and data processing, from agro-ecological zones, which are spatial units related to a soil map. While each AEC has a unique combination of soil and climatic characteristics, related to a particular soil type, agro-ecological zones may contain a number of sets of characteristics, relating to different soil types within the same mapping unit. Sometimes, still broader definitions are applied to agro-ecological zones, to encompass several soil mapping units or climatic zones with similar, but not identical, properties.

Growing period

The concept of the growing period is essential to AEZ, and provides a way of including seasonality in land resource appraisal. In many tropical areas, conditions are too dry during part of the year for crop growth to occur without irrigation, while in temperate climatic regimes crop production in winter is limited by cold temperatures. The growing period defines the period of the year when both moisture and temperature conditions are suitable for crop production.

The growing period provides a framework for summarizing temporally variable elements of climate, which can then be compared with the requirements and estimated responses of the plant. Such parameters as temperature regime, total rainfall and evapotranspiration and the incidence of climatic hazards are more relevant when calculated for the growing period, when they may influence crop growth, rather than averaged over the whole year. Terminology related to the definition of growing periods and their various components is given in Box 2. The estimation of growing period is based on a water balance model which compares rainfall (P) with potential evapo- transpiration (PET). If the growing period is not limited by temperature, the ratio of P/PET determines the start, end and type of growing period.

The determination of the beginning of the growing period is based on the start of the rainy season. The first rains fall on soil which is generally dry at the surface and which has a large soil moisture deficit in the soil profile. In the absence of soil moisture reserves, seedbed preparation, seed germination and the initial growth of crops are therefore entirely dependent on the amount and frequency distribution of these early rains.

Experimental work indicates that the effectiveness of early rains increases considerably once P is equal to, or exceeds, half ET. The growing period continues beyond the rainy season, when crops often mature on moisture reserves stored in the soil profile. Soil moisture storage must therefore be considered in defining the length of the growing period.

In some areas, particularly those where rainfall does not follow a unimodal pattern, P may exceed ET or ET/2 for two or more distinct periods in the year, resulting in more than one LGP per year. The pattern of the growing period describes the proportional representation of each group of years in the total historical series. Different numbers of growing periods. There are obvious differences in plant response depending on whether the growing period is continuous, or whether it is broken into shorter periods of moisture availability separated by dry periods. The number of LGPs is therefore an important consideration in agro-ecological zone definition.

By compiling an inventory of LGPs over a historical sequence of years, the frequency distribution of different annual numbers of LGP can be assessed. Most AEZ studies use reference growing periods, which are calculated from Penman ET for a reference grass crop. These provide a generalized basis for zonation but do not account for the differing abilities of crops to extract soil moisture. Following on from the broad scale studies of the original FAO AEZ project, there has also been a tendency to assume standard figures for soil moisture reserves stored towards the end of the growing period, rather than to base calculations on the actual moisture holding capacities of specific soil types. The national study in Bangladesh, however, where soil moisture reserves are particularly important for residual moisture cropping, allows moisture storage to be adjusted in the range 0-250 mm according to soil type.

While standardization among crops may be permissible in a regional study where a number of crops are considered, information on soil available water holding capacity (AWC) can usually be inferred from the soil inventory, and its inclusion in the moisture balance would improve the accuracy of LGP prediction. The moisture reserve period on the Vertisol (VRe) is sufficiently long for the growth of a short residual moisture crop and, in wetter environments, such soils are often used for this purpose after the rains have ceased. Residual moisture cropping in Bangladesh and Ethiopia takes place on soils with similarly high AWCs.

LGP analysis is based either on average climatic data, or on historic data for individual years. Most early AEZ studies calculated LGP based on average monthly rainfall and PET. While this approach may be acceptable for broad scale regional studies, it fails to capture the temporal variation in LGP, which is determined mainly by inter-annual variations in rainfall distribution. Assessment of LGP for individual years, based on the use of historical rainfall data, enables quantification of the level of risk as well as the potential production under average climatic conditions. Such an approach greatly improves the utility of the assessment, particularly in areas subject to periodic drought. AEZ national studies in Kenya and Bangladesh (FAO, 1993a; Karim, 1994) have used the LGP pattern, as described above, as a means of capturing inter-annual variation in LGP and consequent land suitability and potential yield. The most recent adaptation of the Kenya study evaluates individual LGPs and land suitability over a historical series of years, enabling the results to be expressed in terms of probabilities.

Thermal regime

The thermal regime is the other basic climatic parameter used to define the agro-ecological zones. The thermal regime refers to the amount of heat available for plant growth and development during the growing period. It is usually defined by the mean daily temperature during the growing period. In regional and national AEZ assessments, thermal zones may be defined based on temperature intervals of 5°C or 2.5°C. A more detailed treatment of thermal regimes is often required in temperate or subtropical areas.

Soil mapping unit

The soil mapping unit is the basic unit taken from the soil map. On small-scale maps, soil mapping units rarely comprise single soils, but usually consist of a combination of a dominant soil with minor associated soils. When the various soils of a soil mapping unit occur in a recognizable geographical pattern in defined proportions, they constitute a soil association. If such a pattern is absent, they form a soil complex. An example of the composition of a soil association forming a soil mapping unit.

Each soil type occurring in each soil mapping unit is characterized in terms of its land characteristics and qualities (Box 3), which relate to the edaphic requirements of plants or to land-use requirements for management or conservation.

In the publications of FAO describing land evaluation and AEZ the use of the terms soil unit and land unit is not always consistent. Land, according to the FAO definition (Box 3) includes climate, but soil includes properties of the land surface but excludes climate. A soil or land mapping unit is a spatial entity, which is not necessarily uniform in terms of land characteristics. As a soil unit can easily be confused with a soil mapping unit, the term soil type is suggested to refer to a unit with a specific set of soil characteristics.

Land resource inventory

The land resource inventory is essentially an overlay of climatic and soil information. The resulting units are the agro-ecological zones, which have a unique combination, or a specified range, of soil mapping units, growing period regimes, and thermal regimes; and agro-ecological cells, with unique combina- tions of growing period and thermal regimes and soil types. The relevant land characteristics of each AEC are listed under headings related to agro-climatic constraints and soil or land constraints.

Information on land administration, land tenure and present land use, related to potential land availability, may be incorporated in the land resource inventory. Multiple overlay techniques are particularly applicable when GIS is used, and the resulting AECs and zones are more effective planning units when such information presents an example based on the combination of ten layers of information in the Kenya AEZ study.

Land utilization types and crop adaptability

Assessment of land suitability and potential productivity is made in relation to a specific type of land use under certain production conditions. Following the FAO Framework for Land Evaluation (FAO,1976), land use is classified into Land Utilization Types (Box 3). Relevant land utilization types (LUTs), based on existing and potential land use, have to be clearly identified and described before land suitability evaluation.

The reasons for describing land utilization types are:

- to guide the selection of important agro-ecological characteristics to be included in the land inventory which may influence either output level or environmental impact;
- to support the process of defining algorithms and setting thresholds relating agro-ecological characteristics and potential production level, taking intoaccount:
- the impact of “fixed”, unmodifiable constraints;
- the extent to which a defined LUT is assumed to be able to modify “non-fixed” constraints, e.g., what level of

nutrient application, land improvement and plant care can be assumed?

Quantification of the land use requirements of LUTs provides the basis for estimation of potential yields and for land suitability evaluation. Land-use requirements are grouped according to crop climatic and edaphic adaptability, and requirements for management and conservation. The crop climatic inventory lists requirements, for both photosynthesis and phenology, which bear a relationship to yield in quantity and, where necessary, to yield in quality. The rate of crop photosynthesis, growth and yield are directly related to the assimilation pathway and its response to temperature and radiation. However, the phenological climatic requirements, which must be met, are not specific to a photosynthesis pathway. Edaphic requirements describe crop responses to soil factors, such as nutrient availability or the presence of toxic substances. Requirements for management and conservation include such factors as soil workability and susceptibility to erosion. Procedures for listing and quantifying the requirements of LUTs are given in the adaptability inventories.

AGRO ECOLOGICAL ZONE

Nigeria is found in the Tropics, where the climate is seasonally damp and very humid. The natural vegetative zones that exist in the country are governed by the combined effects of temperature, humidity, rainfall and particularly, the variations that occur in the rainfall. This forms a major influence on the type of indigenous plants that grows successfully in different parts of the country.

The humid tropical forest zone of the South that has longer rains is capable of supporting a number of plantation crops such as cocoa, oil palm, rubber, coffee, cotton and staple crops like, yam, cassava, cocoyam, sweet potatoes, melon, groundnut, rice maize and cowpeas. However, in some parts of the East and many areas near the coast, the high rainfall has led to badly leached soils and severe erosion in some places.

The Northern part of the country representing about 80% of the vegetative zones experiences lower rainfall and shorter rainy season and they make up the Savannah land. The Savannah land forms an excellent natural habitat for a large number of grazing livestock such as cattle, goats, horses, sheep, camels, and donkeys.

The natural vegetative zones resulted from the interaction of climate, humidity, rainfall and soils. These factors have been modified by human activities and man's pattern of land use. Based on the above, Nigeria's agro-ecological zones can be classified into: -

(i) The Mangrove forest and coastal vegetation
(ii) The Freshwater swamp forest
(iii) The tropical high forest zone
(iv) The derived Guinea Savannah
(v) The Guinea Savannah zone
(vi) The Sudan savannah (Short grass savanna)
(vii) The Sahel savannah (Marginal Savanna)
(viii) The Montane vegetation

The Mangrove Forest And Coastal Vegetation

This is found in places near the coast that is under the influence of brackish water commonly found in the Niger Delta. It is also found also in low lying swamp land associated with rivers and Lagoon near the coast and under the influence of the sea. Soil in the mangrove area is poorly aerated with water logged mud and is high in salt content due to the constant flooding by the sea.

The coastal swamp area is not widely cultivated except for swamp rice in places where they are stabilized and non-saline.

The Freshwater Swamp Forest

This area lies immediately inland of the mangrove swamp but on a slightly higher ground. This vegetation belt, on freshwater wetlands occur further inland, beyond the reach of tidal waters. The lagoons or the rivers that overflow their banks in the wet season supply it with fresh water because the area is low lying, therefore it is flooded with rain water and lies under rain for sometimes, eight or nine months of the year.

The area of the country under this agro ecological zone, are Ogun, Benin, Imo, Niger Delta and Cross River. The high influx of water deposit vast quantities of silt, mud and sandy materials into this area. It is a low-lying region, with hardly any part rising over 30m above sea level, thus, it facilitates the development of freshwater swamps along the Niger Delta, drowned estuaries, lagoons and creeks. This zone consists of a mixture of trees. Important among the vegetation of this zone are the various Palm and Fibre plants such as *Raphia* spp., *Raphia vinifera*, the Wine Palm and *Raphia hookeri*, the Roof-mat Palm. They are used for thatching mats and for providing rafter, poles and stiff piassava fibre for the production of brooms. The better-drained areas support Oil Palm trees (*Eleais guineenais*) and big trees like Iroko (*Chlorophora exceisa*). Fishing and fibre-making are the important products of the fresh-water swamp communities.

The Tropical High Forest Zone

This area is characterized with a prolonged rainy season, resulting in high annual rainfall above 2000mm, thereby ensuring an adequate supply of water and promoting perennial tree growth. This luxuriant vegetation belt stretches from the western border of Nigeria to Benin Republic, through a narrow stretch on the Niger-Benue river system into the extensive area in the South-East of the country. This zone is the major source of timber for the large construction and funiture making industry. Of all the zones it contains the most valuable species of vegetation. However due to human activities, this one-time highly forested area has been drastically reduced. Bush fallows, villages and farms are found scattered throughout the zone. Presently the drier end of its inland side is becoming reduced to derived Guinea Savannah because of felling and clearings. In the humid rain forest are found economic cash crops such as Oil Palm, (*Elaeis guineensis*), Cocoa (*Theobroma cacao*), Rubber (*Hevea brasiliensis*) Banana/Plantain (*Musa* spp.) and Cola nut (*Cola nitida*). Also found are some principal staple food crops such as Yam, Cocoyams, Sweet Potato, Maize, Rice, Groundnut, Cowpeas and Beans as well as a number of fruits. A number of timber trees such as the African Mahogany, the scented

Sapele wood (*Entandrophragma cylindricum*) and Iroko (*Chlorophora excelsa*) to mention but three are found in this zone. This zone therefore is very important in terms of food production and timber for construction and cabinet making.

The Derived Guinea Savannah

This zone is found immediately after the tropical rainforest zone. It is the transition between the tropical rainforest and guinea savannah zones. The average annual rainfall and temperature are 1314mm and 26.5ºC respectively. Due to bush burning, overgrazing, cultivation and hunting activities over a long period in the zone, the high forest trees were destroyed and the forest that used to exist is now replaced with a mixture of grasses and scattered trees. The zone is covered with scattered trees and tall grasses. Maize, Cassava, Yam and Rice are the major crops grown in this zone. The savannah in general has an enormous potential for food production in the country. Bush burning and erosion as a result of over grazing by animal especially cattle constitute a major problem to agricultural production in the zone.

The Guinea Savannah

The Guinea Savannah, located in the middle of the country, is the most extensive ecological zone in Nigeria, covering near half of the country. Guinea savannah zone has a unimodal rainfall distribution with the average annual temperature and rainfall of 27.3ºC and 1051.7mm respectively where the wet season lasts for 6–8 months. This zone consists of the larger part of the savannah zone and is sometimes divided into the Southern Guinea Savannah and Northern Guinea Savannah. It is the broadest vegetation zone in the country and it occupies almost half of its area. It extends from Ondo, Edo, Anambra and Enugu States in the South, through Oyo State to beyond Zaria in Kaduna State. It is a belt of mixture of trees and tall grasses in the South, with shorter grasses and less trees in the North. The Guinea Savannah, with its typically short trees and tall grasses, is the most luxuriant of the Savannah vegetation belts in Nigeria. The zone is characterized by low rainfall and long dry period, which call for alternative water supply (irrigation) to enhance full utilization of the zone's potential in agricultural production.

The Guinea savannah is characterized by grasses such as *Pennisetum, Andropogon, Panicum, Chloris, Hyparrhenia, Paspalum* and *Melinis*. These tall grasses are characteristic of the Guinea Savannah proper.

In the Northern Guinea Savannah species such as *Isoberlinia doka* and *I. tomentosa* form the bulk of the scattered woodland. Also found are Locust Bean trees (*Parkia filicoidea*), Shea Butter trees (*Butyrospermum parkii*) and Mangoes (*Mangifera indica*). Comparatively, there are fewer trees in the Northern Guinea Savannah than in the Southern Guinea Savannah and the trees are not as tall as those found in the Southern Guinea Savannah. Most of the tall grasses found in the derived Guinea Savannah, are also found in the Guinea Savannah, however, they are less luxuriant. The appearance of this zone differs from season to season. During the rainy season, the whole zone is green and covered with tall grasses that grow and reach maturity rapidly and thus become fibrous and tough. In the dry season they tend to die and disappear and one can see for kilometers without obstruction. This clearing is due to several periodical bush-burning that occurs during the dry season between November and April, carried out to either assist in farm clearance or hunting.

The Sudan Savannah (Short grass savannah)

The Sudan Savannah zone is found in the Northwest stretching from the Sokoto plains in the West, through the Northern sections of the Central highland. It spans almost the entire Northern States bordering the Niger Republic and covers over one quarter of Nigeria's total area.

The low average annual rainfall of 657.3mm and the prolonged dry season (6-9 months) sustain fewer trees and shorter grasses than the Guinea Savannah. It is characterized by abundant short grasses of 1.5 - 2m and few stunted trees hardly above 15m. It is by far the most densely human populated zone of Northern Nigeria. Thus, the vegetation has undergone severe destruction in the process of clearing land for the cultivation of important economic crops such as Cotton, Groundnut, Sorghum, Millet, Maize and Wheat. The grass vegetation is interspersed with farms and thick bush trees such as Shea Butter tree (*Butyrospermum parkii*) and *Acacia albida*. Also found in the zone are Locust Bean trees (*Parkia filicoidea*), Tamarind tree (*Tamarindus indica*) and Mango (*Mangifera indica*). A large portion of this zone falls within the Tsetse Fly free belt of West Africa and it is excellent for the rearing and breeding of ruminant Livestock (Cattle, Goats, Sheep, Donkeys, Horses and Camels). The nomadic Fulani roam about this zone in search of fodder and water for their Livestock.

The Sahel Savannah (Marginal savannah)

This is the last ecological zoological zone with proximity to the fringes of the fast- encroaching Sahara desert. Occupies about 18 130 km2 of the extreme Northeast corner of Nigeria and is the last vegetation zone in the extreme northern part of the country, close to Lake Chad, where the dry season lasts for up to 9 months and the total average annual rainfall is hardly up to 700mm. Here the vegetation is not only sparse but the grasses are very short. As a rule this zone is not cultivated without irrigation. The people found in this zone are the nomadic herdsmen, and they are careful not to burn the grass found because sparse as it is it provides the only pasture available for their grazing Livestock. It is characterized by either very short grasses of not more than one meter high located in –between sand dunes. The area is dominated by several varieties of the Acacia and Date – palms. The Lake Chad basin, with its seasonally flooded undulating plains, supports a few tall trees. At the same time, the drainage system of rivers and streams into the Lake Chad basin has favored irrigation, without which cultivation would be virtually impossible. The increasing aridity in the area accounts for the progressive drying up of the Lake Chad.

Montane Vegetation

The Montane zone is located in the high altitude areas of the country like Jos Plateau, Mandara, Adamawa Mountain and Obudu Plateau. The zone is characterized by low average annual temperature (21.5ºC). The average annual rainfall is 1450mm. The Montane zone vegetation is covered with grass at the top and base, while forests cover the slopes, favored by moisture-laden wind. The zone has a great potential for the cultivation of Maize, Wheat, Carrot, Cabbage and other exotic vegetables but the mountainous nature of the zone prevents commercial farming. The Fulani who live in great numbers in the area turn the available fields into good pasture for their grazing animals.

The main constraints on feed resources in all the zones are the destruction of perennial tree cover for firewood, bush fires caused by hunters; livestock rearing and overgrazing. These man-made constraints often lead to serious degradation of the pastoral resources and in some cases to an irreversible process of desertification, especially in the Sahel zone.

THE DISTRIBUTION BOUNDARIES OF FLORA AND FAUNA

Of what use are biogeographic classifications? In the past, classifying the flora and fauna into regions was primarily a descriptive event. Today, however, biogeographic classification, like biological taxonomy, is not an end in itself but rather a means to understanding the causative factors involved in evolution, whether they be the vicissitudes of geologic events or the dynamics of biological adaptation. In this sense a classification is not right or wrong so much as it is useful or not.

The sorting of animals and plants into major biogeographic regions is a useful, hypothesis-generating activity. When two taxa of organisms show similar variations in distribution, it is theorized that they have been subject to the same kinds of evolutionary processes, such as ecological constraints that favour certain adaptations or random geographic changes. In a survey of many taxa in a biological community, all may have similar distributional patterns; they may have been restrained by the same geographic barriers or been influenced similarly by climatic factors. When comparing the phytogeographic kingdoms with the zoogeographic realms, one is struck by both the broad agreement in outlines and the differences in details.

Curious discrepancies in these patterns do exist. Some organisms have been able to "skip over" climatic zones so that they are found in both northern and southern temperate zones but not in the intervening tropics. Others appear to have exceptional abilities to disperse to remote, isolated regions and survive. For example, members of the bird family Rallidae (rail) have dispersed throughout many islands, including New Caledonia, Lord Howe Island, Guam, and even the aptly named Inaccessible Island, and the giant tortoises (*Geochelone*) are found on the Galapagos Islands off the west coast of South America as well as on Seychelles off the east coast of Africa.

Discrepancies also exist between animal and plant distributions. For example, a separate kingdom, the South African (Capensic) kingdom, is recognized for plants but not for animals. In New Guinea the flora is classified in the Paleotropical kingdom, but the fauna is not considered to be of the corresponding Paleotropical realm and instead is classified in the Notogaean realm. Some of these discrepancies are more comprehensible than others. The lack of a faunal Capensic division may simply be a function of the greater mobility of animals. Such divisions, if they ever did exist within zoogeography, have been "swallowed up" by the surrounding Neogaean and Afrotropical faunas. Other differences, especially that of the flora and fauna of New Guinea, are less explicable. Land and freshwater plant groups are older than the groups of animals with which they coexist; thus, the major phytogeographic regions reflect a more ancient phase in Earth history than do the zoogeographic regions. Because plants are less mobile, their associations have survived into the present relatively intact. The division of the major regions into minor subdivisions helps to elucidate more recent events in Earth history as well as the dispersal capabilities, adaptive strategies, and ecological relationships of the biota.

The importance of the climate's influence on biotic dispersal must not be overlooked. Marine organisms tend to be distributed along climatic lines, and many terrestrial groups, such as migratory birds, are so mobile that they have become spread across two or more major biogeographic areas. Although they are widely dispersed, they have specialized within northern and southern temperate zones, which are separated by the unsuitable tropical regions between.

These odd, disjunct distributions serve as reminders that biogeographic regions only sketch the outlines of organismal distributions and that they do not explain every case. What they are useful for is to point toward dispersal mechanisms, past climatic corridors, and other important biological phenomena.

Flora

Six floral kingdoms—Boreal (Holarctic), Paleotropical, Neotropical, South African (Capensic), Australian, and Antarctic—are commonly distinguished. These kingdoms are further broken down into subkingdoms and regions, over which there is some dispute. The kingdoms are not sharply delineated, and the families of higher plants vary in the degree to which they are found across the phytogeographic kingdoms, with their distribution being only partly dependent on their age. The following arrangement is based on the work of Ronald Good (1974).

Boreal kingdom

The Boreal, or Holarctic, kingdom consists of Eurasia and North America, which essentially have been a contiguous mass since the Eocene Epoch (55.8 million to 33.9 million years ago). The narrow Bering Strait, between Siberia and Alaska, has existed only since the end of the Pleistocene (some 11,700 years ago). It is no surprise that the differences between the floras of these two continents are minor. Families such as Betulaceae (birch), Brassicaceae (also called Cruciferae), Primulaceae (primrose), Saxifragaceae (saxifrage), Rosaceae (rose), Ranunculaceae (buttercup), and Apiaceae (also called Umbelliferae) are spread across the temperate zone of the Northern Hemisphere.

Arctic and subarctic region

This region is the boreal tundra zone, extending from Spitsbergen (an island in the Arctic Ocean to the north of Norway) around the shores of the Arctic Ocean through Siberia and Arctic North America to Greenland. Flowering plants in this region are poor in diversity, but cryptogams are more diverse.

East Asian region

The East Asian, or Sino-Japanese, region, which has about 300 endemic genera, extends from the slopes of the eastern Himalayas into northeastern China and the Russian Far East, including Taiwan, Japan, and Sakhalin Island . In this region, tropical rainforest to the south merges into deciduous forest to the north. Characteristic plant families are Lauraceae (laurel), Magnoliaceae (magnolia), and Theaceae (tea). There are numerous endemic genera; *Berberis*, *Rhododendron*, and *Juniperus* are characteristic mountain genera.

Western and Central Asian region

Centred on the desert steppes of Central Asia and Mongolia, this floristic zone consists of 200 or more endemic genera and extends from the Caucasus to the Plateau of Tibet, with arid zone plants of the family Chenopodiaceae (goosefoot) and genera such as *Salix* (willow), *Astragalus* (milk vetch), and *Picea* (spruce).

Mediterranean region

The Mediterranean region is the winter rainfall zone of the Holarctic kingdom. It is characterized by sclerophyllous plants mainly of the scrubland type known as maquis. It is difficult to define, however, because many of its characteristic plants (about 250 genera) are centred around but not confined to this region. The region extends entirely around the Mediterranean, from Portugal to Syria. Some classifications place the Canary Islands, which contain a subtropical rainforest biome, in this region, but Good categorizes these islands with the other eastern Atlantic island groups in a separate Macaronesian region, which contains about 30 endemic genera.

Eurosiberian region

The Eurosiberian region extends from Iceland around most of Europe via Siberia to Kamchatka. Conifers of the family Pinaceae—

Pinus (pine), *Larix* (larch), *Picea*, and *Abies* (fir)—grow in vast, monospecific stands and give way to temperate deciduous forest to the south, tundra to the north, and moorlands (which contain Ericaceae [heath family], *Carex* [sedge], and *Sphagnum* moss in suitable areas). The western part of the region is much richer in species than the eastern part: there are about 100 genera that are endemic to Europe, with only about 12 endemic to Siberia.

North American region

The vegetation to the east of the Bering Strait, in the North American region, closely resembles that to the west, in the Eurosiberian region, with slight variations. The conifer genera *Tsuga* (hemlock), *Sequoia* (redwood), and others replace their Eurosiberian counterparts, and there are nine endemic families of flowering plants. Good and others separate the eastern (Atlantic) and western (Pacific) halves of North America into distinct regions, with 100 genera endemic to the Atlantic region and 300 endemic to the Pacific, although these endemic taxa comprise only a small part of the total flora.

Paleotropical kingdom

This kingdom extends from Africa, excluding strips along the northern and southern edges, through the Arabian peninsula, India, and Southeast Asia eastward into the Pacific. Plant families that extend over much of the region include the families Pandanaceae (screw pine) and Nepenthaceae (East Indian pitcher plant). The flora in this huge region, however, is not homogenous: 98 percent of species of Hawaiian flora are endemic, as are 70 percent of Fijian floral species and 60 percent of the floral species of New Caledonia. The divisions of the kingdom are disputed, but those most commonly recognized are the Malesian, Indoafrican, and Polynesian subkingdoms.

Malesian subkingdom

This subkingdom encompasses the islands of Southeast Asia and the Malay Peninsula, extending as far east as the mainland of New Guinea. Although it had sometimes been included with

India in an Indo-Malayan region, the flora of what C.G.G.J. van Steenis (1950) called Malesia forms a tight-knit unity that can be subdivided into three divisions: a western area covering the Malay Peninsula, Sumatra, Borneo, and the Philippines; a southern area of Java and the Lesser Sundas; and an eastern area of Celebes, the Moluccas, and New Guinea. The region boasts approximately 400 endemic genera (20 percent of the total flora of the Earth), of which 130 genera are found in the western division, 15 in the southern division, and 150 in the eastern division. The biome types range from tropical rainforest to montane and cloud forest, with drier biome types in areas of the southern division. The rainforest biomes in the western part of the region are characterized by the dominance of the family Dipterocarpaceae, although the Guttiferae, Moraceae (mulberry), and Annonaceae (custard apple) families also are found throughout.

Indoafrican subkingdom

In the Indoafrican subkingdom, curiously little distinction is to be made between the flora of Africa (south of the Sahara) and the Indian subcontinent, Myanmar (Burma), and southern China. These areas are narrowly connected by a corridor running through the Arabian Peninsula and southern Iran. The flora of the island of Madagascar is the most divergent in the region and is often regarded as forming a separate region; the island has 12 endemic families and 350 endemic genera, although these form only about a quarter of the total. The flora of Sri Lanka has almost as much in common with Malesia as it does with India. Vegetation ranges from rainforest to semiarid steppe. The families Leguminoseae (legume) and Asteraceae (aster), often called Compositae, achieve their greatest diversity in the region, together with Combretaceae (Indian almond) and, in the arid south of Madagascar, Didiereaceae. Characteristic genera include the grasses *Andropogon* and *Panicum* and the giant baobab (*Adansonia*). In the montane (Afroalpine) zones *Lobelia*, *Senecio*, and *Erica* (heath) are characteristic. About 50 endemic genera define a desert zone extending from the Sahara to northwestern India; 500 are endemic to tropical Africa, 120 to India, and 300 to continental Southeast Asia, but the boundaries of these zones are poorly defined and the distributions of the endemics are only weakly coterminous.

Polynesian subkingdom

In many respects the Pacific islands are outliers of Malesia, but each of the four main divisions within the Polynesian subkingdom—Hawaii; the remaining portion of Polynesia; Melanesia and Micronesia; and New Caledonia, with Lord Howe and Norfolk islands—has a high number of endemic taxa. Hawaii has more than 40 endemic genera; Polynesia, excluding Hawaii, has almost 20; the division of Melanesia and Micronesia has 38, with 17 confined to Fiji; and New Caledonia has 135 among a total of 600 genera native to the island. Only 21 of the subkingdom's endemic genera occur in more than one of the four divisions. The unbalanced aspect of the flora is illustrated by the dominance, among the endemics, of the Arecaceae family, sometimes called Palmae—there are more than 35 endemic genera of palms in the Polynesian subkingdom—and a few other families.

Neotropical kingdom

Essentially the Neotropical kingdom covers all but the extreme southern tip and southwestern strip of South America; Central America; Mexico, excluding the dry north and centre; and beyond to the West Indies and the southern tip of Florida. The vegetation ranges from tropical rainforest in the Amazon and Orinoco basins to open savanna in Venezuela (the Llanos) and Argentina (the Pampas). Forty-seven families and nearly 3,000 genera of flowering plants are endemic to this kingdom; some families, including Bromeliaceae (pineapple) and Cactaceae (cactus), are virtually confined to this kingdom. Within the kingdom, Central America, which includes Mexico and the isthmus, the West Indies, the Venezuela-Guyana region, Brazil, the Andes, and the Pampas all have some measure of endemicity. Although impoverished, the Juan Fernández Islands and the Desventurados Islands, located off the west coast of Chile, exhibit a high endemicity with a general Neotropical affinity.

South African kingdom

The South African, or Capensic, kingdom consists of the southern and southwestern tip of Africa, the area around the Cape of Good Hope (hence, the designation "Capensic"). It is remarkably rich in plants; 11 families and 500 genera are endemic. This is the smallest of the phytogeographic kingdoms. The winter rainfall climatic regime mimics that of the Mediterranean region, and the general aspect of the vegetation is akin to the scrubland vegetation (maquis) of that region. At the edges of this tiny, restricted zone, the flora merges into the typical flora of Africa—Paleotropical.

Australian kingdom

The continent of Australia forms a kingdom sharply distinct from the Paleotropic. Rainforest biomes—from tropical in the north that include monsoon forests to temperate in the far south, especially Tasmania—occur along the eastern seaboard. Woodlands of *Eucalyptus* cover much of the eastern third of the continent, and a mosaic of remarkable temperate forests and *Banksia* heathland are found in the southwest. (These two elements of Australian flora, while conspicuous, are not endemic; there are a few species of *Eucalyptus* in eastern New Guinea, New Britain, the Lesser Sundas, and the Philippines, and one species of *Banksia* is found in New Guinea.) Otherwise much of the vegetation is semiarid or adapted to the dryness. About 19 families and 500 genera are endemic. Only the tropical rainforests of northeastern Queensland have a mixed flora, with a notable Malesian element.

8

Geographical Range and Aquatic System

GEOGRAPHIC RANGE

The range of a species is the geographical area within which that species can be found. The range may emphasize the limits of a species occurrence or it may be more detailed, depending upon the information available and the objectives in providing it. For example, the IUCN describes the geographical range of Pan troglodytes as wide but discontinuous across Equatorial Africa between 13 degrees North and 7 degrees South, occurring from southern Senegal across the forested belt north of the Congo River to western Uganda and western Tanzania from sea-level to 2,800m above sea level.

AQUATIC ECOSYSTEM

An aquatic ecosystem is an ecosystem in a body of water. Communities of organisms that are dependent on each other and on their environment live in aquatic ecosystems. The two main types of aquatic ecosystems are marine ecosystems and freshwater ecosystems.

Types

Marine

Marine ecosystems, the largest of all ecosystems, cover approximately 71% of the Earth's surface and contain approximately 97% of the planet's water. They generate 32% of the world's net primary production. They are distinguished from freshwater ecosystems by the presence of dissolved compounds, especially salts, in the water. Approximately 85% of the dissolved materials in seawater are sodium and chlorine. Seawater has an average salinity of 35 parts per thousand of water. Actual salinity varies among different marine ecosystems.

Marine ecosystems can be divided into many zones depending upon water depth and shoreline features. The oceanic zone is the vast open part of the ocean where animals such as whales, sharks, and tuna live. The benthic zone consists of substrates below water where many invertebrates live. The intertidal zone is the area between high and low tides; in this figure it is termed the littoral zone. Other near-shore (neritic) zones can include estuaries, salt marshes, coral reefs, lagoons and mangrove swamps. In the deep water, hydrothermal vents may occur where chemosynthetic sulfur bacteria form the base of the food web.

Classes of organisms found in marine ecosystems include brown algae, dinoflagellates, corals, cephalopods, echinoderms, and sharks. Fishes caught in marine ecosystems are the biggest source of commercial foods obtained from wild populations.

Environmental problems concerning marine ecosystems include unsustainable exploitation of marine resources (for example overfishing of certain species), marine pollution, climate change, and building on coastal areas.

Freshwater

Freshwater ecosystems cover 0.78% of the Earth's surface and inhabit 0.009% of its total water. They generate nearly 3% of its net primary production. Freshwater ecosystems contain 41% of the world's known fish species.

There are three basic types of freshwater ecosystems:

- Lentic: slow moving water, including pools, ponds, and lakes.

- Lotic: faster moving water, for example streams and rivers.
- Wetlands: areas where the soil is saturated or inundated for at least part of the time.

Lentic

Lake ecosystems can be divided into zones. One common system divides lakes into three zones. The first, the littoral zone, is the shallow zone near the shore. This is where rooted wetland plants occur. The offshore is divided into two further zones, an open water zone and a deep water zone. In the open water zone (or photic zone) sunlight supports photosynthetic algae, and the species that feed upon them. In the deep water zone, sunlight is not available and the food web is based on detritus entering from the littoral and photic zones. Some systems use other names. The off shore areas may be called the pelagic zone, the photic zone may be called the limnetic zone and the aphotic zone may be called the profundal zone. Inland from the littoral zone one can also frequently identify a riparian zone which has plants still affected by the presence of the lake—this can include effects from windfalls, spring flooding, and winter ice damage. The production of the lake as a whole is the result of production from plants growing in the littoral zone, combined with production from plankton growing in the open water.

Wetlands can be part of the lentic system, as they form naturally along most lake shores, the width of the wetland and littoral zone being dependent upon the slope of the shoreline and the amount of natural change in water levels, within and among years. Often dead trees accumulate in this zone, either from windfalls on the shore or logs transported to the site during floods. This woody debris provides important habitat for fish and nesting birds, as well as protecting shorelines from erosion.

Two important subclasses of lakes are ponds, which typically are small lakes that intergrade with wetlands, and water reservoirs. Over long periods of time, lakes, or bays within them, may gradually become enriched by nutrients and slowly fill in with organic sediments, a process called succession. When humans use the watershed, the volumes of sediment entering the lake can accelerate this process. The addition of sediments and nutrients to a lake is known as eutrophication.

Ponds

Ponds are small bodies of freshwater with shallow and still water, marsh, and aquatic plants. They can be further divided into four zones: vegetation zone, open water, bottom mud and surface film. The size and depth of ponds often varies greatly with the time of year; many ponds are produced by spring flooding from rivers. Food webs are based both on free-floating algae and upon aquatic plants. There is usually a diverse array of aquatic life, with a few examples including algae, snails, fish, beetles, water bugs, frogs, turtles, otters and muskrats. Top predators may include large fish, herons, or alligators. Since fish are a major predator upon amphibian larvae, ponds that dry up each year, thereby killing resident fish, provide important refugia for amphibian breeding. Ponds that dry up completely each year are often known as vernal pools. Some ponds are produced by animal activity, including alligator holes and beaver ponds, and these add important diversity to landscapes.

Lotic

The major zones in river ecosystems are determined by the river bed's gradient or by the velocity of the current. Faster moving turbulent water typically contains greater concentrations of dissolved oxygen, which supports greater biodiversity than the slow moving water of pools.

These distinctions form the basis for the division of rivers into upland and lowland rivers. The food base of streams within riparian forests is mostly derived from the trees, but wider streams and those that lack a canopy derive the majority of their food base from algae. Anadromous fish are also an important source of nutrients. Environmental threats to rivers include loss of water, dams, chemical pollution and introduced species. A dam produces negative effects that continue down the watershed. The most important negative effects are the reduction of spring flooding, which damages wetlands, and the retention of sediment, which leads to loss of deltaic wetlands.

Wetlands

Wetlands are dominated by vascular plants that have adapted to saturated soil. There are four main types of wetlands: swamp, marsh, fen and bog (both fens and bogs are types of mire). Wetlands are the most productive natural ecosystems in the world because of the proximity of water and soil. Hence they support large numbers of plant and animal species. Due to their productivity, wetlands are often converted into dry land with dykes and drains and used for agricultural purposes. The construction of dykes, and dams, has negative consequences for individual wetlands and entire watersheds. Their closeness to lakes and rivers means that they are often developed for human settlement. Once settlements are constructed and protected by dykes, the settlements then become vulnerable to land subsidence and ever increasing risk of flooding. The Louisiana coast around New Orleans is a well-known example; the Danube Delta in Europe is another.

Functions

Aquatic ecosystems perform many important environmental functions. For example, they recycle nutrients, purify water, attenuate floods, recharge ground water and provide habitats for wildlife. Aquatic ecosystems are also used for human recreation, and are very important to the tourism industry, especially in coastal regions.

The health of an aquatic ecosystem is degraded when the ecosystem's ability to absorb a stress has been exceeded. A stress on an aquatic ecosystem can be a result of physical, chemical or biological alterations of the environment. Physical alterations include changes in water temperature, water flow and light availability. Chemical alterations include changes in the loading rates of biostimulatory nutrients, oxygen consuming materials, and toxins. Biological alterations include over-harvesting of commercial species and the introduction of exotic species. Human populations can impose excessive stresses on aquatic ecosystems. There are many examples of excessive stresses with negative consequences. Consider three. The environmental history of the Great Lakes of North America illustrates this problem, particularly how multiple stresses, such as water pollution, over-harvesting and invasive species can combine. The Norfolk Broadlands in England illustrate similar decline with pollution and invasive species. Lake Pontchartrain along the Gulf of Mexico illustrates the negative effects of different stresses including levee construction, logging of swamps, invasive species and salt water intrusion.

Abiotic characteristics

An ecosystem is composed of biotic communities that are structured by biological interactions and abiotic environmental factors. Some of the important abiotic environmental factors of aquatic ecosystems include substrate type, water depth, nutrient levels, temperature, salinity, and flow. It is often difficult to determine the relative importance of these factors without rather large experiments. There may be complicated feedback loops. For example, sediment may determine the presence of aquatic plants, but aquatic plants may also trap sediment, and add to the sediment through peat.

The amount of dissolved oxygen in a water body is frequently the key substance in determining the extent and kinds of organic life in the water body. Fish need dissolved oxygen to survive, although their tolerance to low oxygen varies among species; in extreme cases of low oxygen some fish even resort to air gulping. Plants often have to produce aerenchyma, while the shape and size of leaves may also be altered. Conversely, oxygen is fatal to many kinds of anaerobic bacteria.

Nutrient levels are important in controlling the abundance of many species of algae. The relative abundance of nitrogen and phosphorus can in effect determine which species of algae come to dominate. Algae are a very important source of food for aquatic life, but at the same time, if they become over-abundant, they can cause declines in fish when they decay. Similar over-abundance of algae in coastal environments such as the Gulf of Mexico produces, upon decay, a hypoxic region of water known as a dead zone.

The salinity of the water body is also a determining factor in the kinds of species found in the water body. Organisms in marine ecosystems tolerate salinity, while many freshwater organisms are intolerant of salt. The degree of salinity in an estuary or delta is an important control upon the type of wetland (fresh, intermediate, or brackish), and the associated animal species. Dams built upstream may reduce spring flooding, and reduce sediment accretion, and may therefore lead to saltwater intrusion in coastal wetlands.

Freshwater used for irrigation purposes often absorbs levels of salt that are harmful to freshwater organisms.

Biotic characteristics

The biotic characteristics are mainly determined by the organisms that occur. For example, wetland plants may produce dense canopies that cover large areas of sediment—or snails or geese may graze the vegetation leaving large mud flats. Aquatic environments have relatively low oxygen levels, forcing adaptation by the organisms found there. For example, many wetland plants must produce aerenchyma to carry oxygen to roots. Other biotic characteristics are more subtle and difficult to measure, such as the relative importance of competition, mutualism or predation. There are a growing number of cases where predation by coastal herbivores including snails, geese and mammals appears to be a dominant biotic factor.

Autotrophic organisms

Autotrophic organisms are producers that generate organic compounds from inorganic material. Algae use solar energy to generate biomass from carbon dioxide and are possibly the most important autotrophic organisms in aquatic environments. The more shallow the water, the greater the biomass contribution from rooted and floating vascular plants. These two sources combine to produce the extraordinary production of estuaries and wetlands, as this autotrophic biomass is converted into fish, birds, amphibians and other aquatic species.

Chemosynthetic bacteria are found in benthic marine ecosystems. These organisms are able to feed on hydrogen sulfide in water that comes from volcanic vents. Great concentrations of animals that feed on these bacteria are found around volcanic vents. For example, there are giant tube worms (*Riftia pachyptila*) 1.5 m in length and clams (*Calyptogena magnifica*) 30 cm long.

Heterotrophic organisms

Heterotrophic organisms consume autotrophic organisms and use the organic compounds in their bodies as energy sources and as raw materials to create their own biomass. Euryhaline organisms are salt tolerant and can survive in marine ecosystems, while stenohaline or salt intolerant species can only live in freshwater environments.

AQUATIC ECOSYSTEMS AND GLOBAL CLIMATE CHANGE

Aquatic ecosystems are critical components of the global environment. In addition to being essential contributors to biodiversity and ecological productivity, they also provide a variety of services for human populations, including water for drinking and irrigation, recreational opportunities, and habitat for economically important fisheries. However, aquatic systems have been increasingly threatened, directly and indirectly, by human activities. In addition to the challenges posed by land-use change, environmental pollution, and water diversion, aquatic systems are expected to soon begin experiencing the added stress of global climate change.

"Aquatic Ecosystems and Global Climate Change" is the seventh in a series of reports examining the potential impacts of climate change on the U.S. environment. It details the likely impacts of climate change over the next century on U.S. aquatic ecosystems.

Report authors, Drs. N. LeRoy Poff, Mark Brinson, and John Day, Jr. find:

- Increases in water temperatures as a result of climate change will alter fundamental ecological processes and the geographic distribution of aquatic species. Such impacts may be ameliorated if species attempt to adapt by migrating to suitable habitat. However, human alteration of potential migratory corridors may limit the ability of species to relocate, increasing the likelihood of species extinction and loss of biodiversity.
- Changes in seasonal patterns of precipitation and runoff will alter hydrologic characteristics of aquatic systems, affecting species composition and ecosystem productivity. Populations of aquatic organisms are sensitive to changes in the frequency, duration, and timing of extreme precipitation events, such as floods or droughts. Changes in the seasonal timing of snowmelt will alter stream flows, potentially interfering with the reproduction of many aquatic species.
- Climate change is likely to further stress sensitive freshwater and coastal wetlands, which are already adversely affected by a variety of other human impacts, such as altered flow regimes and deterioration of water quality. Wetlands are a critical habitat for many species that are poorly adapted for other environmental conditions and serve as important components of coastal and marine fisheries.
- Aquatic ecosystems have a limited ability to adapt to climate change. Reducing the likelihood of significant impacts to these systems will be critically dependent on human activities that reduce other sources of ecosystem stress and enhance adaptive capacity. These include maintaining riparian forests, reducing nutrient loading, restoring damaged ecosystems, minimizing groundwater withdrawal, and strategically placing any new reservoirs to minimize adverse effects.

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Climate change of the magnitude projected for the United States over the next 100 years will cause significant changes to temperature regimes and precipitation patterns across the United States. Such alterations in climate pose serious risks for inland freshwater ecosystems (lakes, streams, rivers, wetlands) and coastal wetlands, and they may adversely affect numerous critical services they provide to human populations.

The geographic ranges of many aquatic and wetland species are determined by temperature. Average global surface temperatures are projected to increase by 1.5 to 5.8oC by 2100 (Houghton et al., 2001), but increases may be higher in the United States (Wigley, 1999). Projected increases in mean temperature in the United States are expected to greatly disrupt present patterns of plant and animal distributions in freshwater ecosystems and coastal wetlands. For example, cold-water fish like trout and salmon are projected to disappear from large portions of their current geographic range in the continental United States, when warming causes water temperature to exceed their thermal tolerance limits. Species that are isolated in habitats near thermal tolerance limits (like fish in Great Plains streams) or that occupy rare and vulnerable habitats (like alpine wetlands) may become extinct in the United States. In contrast, many fish species that prefer warmer water, such as largemouth bass and carp, will potentially expand their ranges in the United States and Canada as surface waters warm.

The productivity of inland freshwater and coastal wetland ecosystems also will be significantly altered by increases in water temperatures. Warmer waters are naturally more productive, but the particular species that flourish may be undesirable or even harmful. For example, the blooms of "nuisance" algae that occur in many lakes during warm, nutrient-rich periods can be expected to increase in frequency in the future. Large fish predators that require cool water may be lost from smaller lakes as surface water temperatures warm, and this may indirectly cause more blooms of nuisance algae, which can reduce water quality and pose potential health problems.

Warming in Alaska is expected to melt permafrost areas, allowing shallow summer groundwater tables to drop; the subsequent drying of wetlands will increase the risk of catastrophic peat fires and the release of vast quantities of carbon dioxide (CO2) and possibly methane into the atmosphere.

In addition to its independent effects, temperature changes will act synergistically with changes in the seasonal timing of runoff to freshwater and coastal systems. In broad terms, water quality will probably decline greatly, owing to expected summertime reductions in runoff and elevated temperatures. These effects will carry over to aquatic species because the life cycles of many are tied closely to the availability and seasonal timing of water from precipitation and runoff. In addition, the loss of winter snowpack will greatly reduce a major source of groundwater recharge and summer runoff, resulting in a potentially significant lowering of water levels in streams, rivers, lakes, and wetlands during the growing season.

The following summarizes the current understanding regarding the potential impacts of climate change on U.S. aquatic ecosystems:

1. Aquatic and wetland ecosystems are very vulnerable to climate change. The metabolic rates of organisms and the overall productivity of ecosystems are directly regulated by temperature. Projected increases in temperature are expected to disrupt present patterns of plant and animal distribution in aquatic ecosystems. Changes in precipitation and runoff modify the amount and quality of habitat for aquatic organisms, and thus, they indirectly influence ecosystem productivity and diversity.
2. Increases in water temperature will cause a shift in the thermal suitability of aquatic habitats for resident

species. The success with which species can move across the landscape will depend on dispersal corridors, which vary regionally but are generally restricted by human activities. Fish in lowland streams and rivers that lack northward connections, and species that require cool water (e.g., trout and salmon), are likely to be the most severely affected. Some species will expand their ranges in the United States.

3. Seasonal shifts in stream runoff will have significant negative effects on many aquatic ecosystems. Streams, rivers, wetlands, and lakes in the western mountains and northern Plains are most likely to be affected, because these systems are strongly influenced by spring snowmelt and warming will cause runoff to occur earlier in winter months.
4. Wetland loss in boreal regions of Alaska and Canada is likely to result in additional releases of CO2 into the atmosphere. Models and empirical studies suggest that global warming will cause the melting of permafrost in northern wetlands. The subsequent drying of these boreal peatlands will cause the organic carbon stored in peat to be released to the atmosphere as CO2 and possibly methane.
5. Coastal wetlands are particularly vulnerable to sea-level rise associated with increasing global temperatures. Inundation of coastal wetlands by rising sea levels threatens wetland plants. For many of these systems to persist, a continued input of suspended sediment from inflowing streams and rivers is required to allow for soil accretion.
6. Most specific ecological responses to climate change cannot be predicted, because new combinations of native and non-native species will interact in novel situations.Such novel interactions may compromise the reliability with which ecosystem goods and services are provided by aquatic and wetland ecosystems.

7. Increased water temperatures and seasonally reduced streamflows will alter many ecosystem processes with potential direct societal costs. For example, warmer waters, in combination with high nutrient runoff, are likely to increase the frequency and extent of nuisance algal blooms, thereby reducing water quality and posing potential health problems.
8. The manner in which humans adapt to a changing climate will greatly influence the future status of inland freshwater and coastal wetland ecosystems. Minimizing the adverse impacts of human activities through policies that promote more science-based management of aquatic resources is the most successful path to continued health and sustainability of these ecosystems. Management priorities should include providing aquatic resources with adequate water quality and amounts at appropriate times, reducing nutrient loads, and limiting the spread of exotic species.

Overall, these conclusions indicate climate change is a significant threat to the species composition and function of aquatic ecosystems in the United States. However, critical uncertainties exist regarding the manner in which specific species and whole ecosystems will respond to climate change. These arise both from uncertainties about how regional climate will change and how complex ecological systems will respond. Indeed, as climate change alters ecosystem productivity and species composition, many unforeseen ecological changes are expected that may threaten the goods and services these systems provide to humans.

AQUACULTURE SYSTEMS AND SUSTAINABILITY

Sustainable development and sustainability are complex issues that are difficult to define and apply to aquaculture. The "systems approach", however, can assist understanding of these issues, as they relate to aquaculture development.

The term sustainability has been defined in various ways but perhaps the most widely used is based on the definition of "sustainable development" in the Brundtland report: "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". An even more succinct definition is that of the International Union for the Conservation of Nature (IUCN): "sustainable development improves people's quality of life within the context of the Earth's carrying capacity". These definitions contain two key concepts: meeting the present and future needs of the world's people, and accepting the limitations of the environment to provide resources and to receive wastes for the present and for the future. The Food and Agriculture Organization of the United Nations (FAO), in particular, recognized that increased capacity at the national level is required to achieve sustainable development by including the need for "institutional change" in definitions of sustainable agricultural development (FAO, 1995). The recognition that institutions are important highlights the need for education and training, effective institutional arrangements and a legal and policy framework to underpin sustainable development of agriculture, and indeed aquaculture.

Sustainability is commonly split into three separate components: social sustainability (SS); economic sustainability (EcS); environmental sustainability (ES). Whilst social sustainability criteria are difficult to define, the definition of economic and environmental sustainability are providing a basis from which management options can evolve in aquaculture projects. To take sustainability to a more practical level requires consideration of environmental, social and economic issues in aquaculture development. Thus, the approach to sustainability implies a systems approach.

There are general guidelines available on the different issues to consider. The Code of Conduct on Responsible Fisheries (CCRF), adopted by the FAO Conference in 1995 in particular, identifies a number of key issues. The Code sets out principles and international standards of behaviour for responsible practices, to ensure effective conservation, management and development of living aquatic resources while, at the same time, recognizing the nutritional, economic, social, environmen-tal and cultural importance of fisheries and aquaculture, and the interests of all those involved in these sectors. The Code's Article on Aquaculture Development contains provisions relating to aquaculture, including culture-based fisheries. Fundamentally, the Code recognizes the importance of activities that support the development of aquaculture at different levels:

* the producer level;
* the local area, i.e., the farm and its integration into local area management and rural development schemes;
* the national institutional and policy environment; and
* international and transboundary issues.

The Code identifies many key principles in development of management strategies based on an understanding of aquaculture systems-from the farm to national and international levels. It also provides a basis for a systems approach.

THE SYSTEMS APPROACH

Farm Level

There is a lot of information on aquaculture farming systems, and various definitions are available, such as the level of intensity of management and output, and degree of integration with other on-farm activities. A considerable literature exists on integrated (agriculture-aquaculture and vice versa) farming systems. However, there are a wide range of culture species, culture facilities and management practices in use, and thus a very wide range of farming systems.

Key factors to be understood in the functioning of a farming system are the technologies of production and social, economic and environmental aspects. At the technology level, feeds, feed additives and fertilizers, water quality, seed quality and availability, chemoterapeutants and other chemicals, disposal of wastes that may adversely affect human health and/or the environment, and food safety of aquaculture products all require consideration. It has also been emphasised that a better understanding of the microbial populations in aquaculture systems, their interaction with the health of the farmed animals, and their role in maintaining a healthy aquatic environment are required.

The systems approach at the farm level can be used to understand and improve the efficiency of use of key natural resources-particularly water, nutrients, land, seed and financial resources. When focussing on the mix of all sustainability criteria through a systems approach, we have to deal with such factors as: appropriate densities, production and husbandry systems geared to the animal's health, maintaining ecological balance within the pond or other growout habitat, and provision of optimal social and economic benefits. It is inevitable that impacts on natural resources will become an increasingly important issue in the new millennium, and the systems approach can be used to analyse and develop the solutions required for more sustainable use of natural resources.

A wide range of management systems is already employed in aquaculture operations with varying degrees of success. Given that aquaculture systems range from small, relatively self-contained farms for subsistence, to large-scale commercial units for trade purposes, variable success is hardly surprising. Thus, a "one-size fits all" approach is unlikely to be successful. A systematic approach to production management, however, allows the farmer to manipulate and control production inputs that will result in more efficient, cost-effective production and minimize excessive outputs with negative environmental impacts. There is a tremendous body of information on site selection, farm construction and design features, aquatic animal health management, broodstock and seed production and care, production techniques, the use of appropriate feeds, feed additives and fertilizers, water and sediment management, including effluent control, and other topics.

The challenge is to optimize dissemination and use of such information and experience. The systems approach can also be used for aquatic animal health management. Here the emphasis needs to move more towards management procedures, policies and products that can prevent or effectively eradicate significant pathogens, prevent re-infection through contaminants, and manage diseases in an environmentally sustainable manner. Subasinghe et al. (1998) provide a discussion of the role of the systems approach in aquatic animal health management.

The Local Level

The systems approach at the local level recognizes that individual farms cannot be seen in isolation, and that there are many interactions between an aquaculture farm and the external environment-including environmental resources and local communities. Furthermore, there can be significant cumulative effects where there are large numbers of farms crowded in small areas.

Environmental interactions with aquaculture arise from a wide range of inter related factors including availability, amount and quality of resources; type of species cultured; size of farm; culture systems management; and environmental characteristics of the farm location. Environmental interactions are not limited to impacts of aquaculture on the environment, but include environmental impacts on aquaculture and impacts of aquaculture on aquaculture. Perhaps less well known or documented are the many ways that aquaculture can contribute to environmental improvement, for example mollusc farms' desedimentation or improved nutrient turnover, or water storage on small-scale freshwater farms.

At the local level, social and institutional interactions are also important and need to be better understood, for example:

* participation of, and benefits to, rural communities;
* institutional support through extension services;
* access to information etc.

A systems approach attempts to understand these linkages and develop management strategies based on such understanding.

The future of integration of aquaculture into local ecological and social systems requires more focus on local area development planning. Fortunately, increasing attention is being given to such issues, particularly in coastal areas. Integrated coastal management (ICM) is a process that addresses the use, sustainable development and protection of coastal areas, and according to GESAMP (1996) "comprehensive area-specific marine management and planning is essential for maintaining the long-term ecological integrity and productivity and economic benefit of coastal regions". ICM is made operational through such activities as:

* land use zoning and buffer zones;
* regulations, including permitting to undertake different activities;
* nonregulatory mechanisms;
* construction of infrastructure;
* conflict resolution procedures;
* voluntary monitoring; and
* impact assessment techniques.

More participatory approaches to planning of aquaculture development will also be given attention with the move towards integrated development planning. Practical experience in implementation ICM for aquaculture is limited, which is in large measure because of the absence of adequate policies and legislation and institutional problems, such as a lack of unitary authorities with sufficiently broad powers and responsibilities, as well as limited training and education of people concerned.

In inland rural areas, increasing attention is being given to integration of aquaculture into rural development and special area management plans. Increasing emphasis is also being given to promotion of aquaculture for poverty alleviation. Such an approach requires emphasis on immediate social needs and people's livelihoods (and how aquaculture might meet these needs and contribute to improved livelihoods) rather than a technology/ aquaculture driven approach. The emphasis on aquaculture for development, rather than development of aquaculture may lead to some fundamental changes in the approach to promotion of aquaculture in the coming years.

National, Regional and International Levels

At the national level, government policy, and institutional and human capacity are most important in providing a strong foundation for aquaculture to develop in a su. These issues are covered extensively in the Conference's policy session and are not discussed in detail here, except by recognition that most community and farm activities are influenced by national-level policy, legislation and institutional support.

For example, the level of aquatic animal disease affecting small-scale producers or enhanced fisheries is related to national policies for quarantine and movement of live aquatic animals, which affect the risk of exposure of small-scale producers to serious aquatic pathogens. Inter-and intra-country trading patterns and movement of aquatic animals also affect these risks. International conventions (e.g. the Convention on Biodiversity), trade and consumer preferences, all clearly impact aquaculture development at a local level.

9

Ecology and Health Geography

BEGINNING OF ECOLOGY

Early man was a successful practicing ecologist. He survived in a rich and competitive biotic community, and his relationship to this community was continually intimate. He was by no means the strongest, the swiftest, nor the hardiest among his congeners, but he possessed several distinct advantages. He had a close effective social organization, he had unusual manipulative ability, and he had, of course, an emerging intelligence. Thus he developed tools and fire in early Paleolithic time (500,000 to 1,000,000 years ago), and he accumulated knowledge at a faster rate than other primates.

Much of this knowledge was ecological. It was knowledge of his environment and the most effective use of it. It was detailed knowledge of food and water resources, some of which can still be seen in the "primitive" peoples of today. The Kalahari bushmen, for example, can find water in a barren desert where other men would surely die of thirst. The Australian aborigine can locate grubs and lizards in the Australian deserts far better than a modern biologist. Bates found on the Micronesian atoll of Ifaluk that the native people had a detailed ecologic knowledge of the plants on the islands and the use to which each could be put in terms of food, medicine, construction and ornament. They also possessed detailed knowledge of the reefs and sea around them. In all societies of hunter-gatherers there was strong selective pressure against the nonecologist. This rigorous natural selection prevailed throughout the two million years of Paleolithic man, and before that the 10 to 15 million years of Pliocene and Miocene hominids and protohominids, the forerunners of man.

There is increasing evidence that early man was well adapted to his environment. The popular conception that he barely clung to life through a precarious and difficult struggle is definitely misleading. Recent studies of both ancient and modern hunter-gatherers have shown that they frequently have had an abundant life, with very ample resources and sustenance. Some present-day primitive peoples are declining, of course, but usually as a result of modern forces-a deteriorating environment or competition from agricultural peoples. Other studies on former hunter-gatherers have shown that malnutrition was rare, starvation infrequent, and chronic diseases, as we know them today, of relatively low incidence—all evidence of sound ecologic balance in their way of life. There was, however, high infant mortality, primarily through infectious disease, and high "social mortality" (infanticide, geronticide, warfare, etc.), and these served as primary mechanisms of population regulation.

The ecological ability of early man does not necessarily mean that he was a good conservationist. Guthrie has pointed out that the concept of early man living in blissful harmony with his environment is a serious distortion of facts. Early man knew enough practical ecology to survive and even prosper, but he exploited his environment at every opportunity. He was a persistent forager and relentless hunter whose primary goal was survival. He was often nomadic. Some scholars have felt that the overzealous hunting of early man contributed to the widespread extinction of animals in the Pleistocene Epoch. Although this is a controversial hypothesis, there is some evidence that early man was not always conservative in hunting or environmental protection. For example, plains Indians of North America were known to have killed many more bison than they could utilize by driving them over cliffs. Apart from some of these extravagances, early man did feel a close kinship with nature, and considered himself a small part of a vast scheme.

IMPORTANCE IN ECOLOGY

Microbes are critical to the processes of decomposition required to cycle nitrogen and other elements back to the natural world.

Hygiene

Hygiene is the avoidance of infection or food spoiling by eliminating microorganisms from the surroundings. As microorganisms, particularly bacteria, are found practically everywhere, this means in most cases the reduction of harmful microorganisms to acceptable levels. However, in some cases it is required that an object or substance be completely sterile, i.e. devoid of all living entities and viruses. A good example of this is a hypodermic needle.

In food preparation microorganisms are reduced by preservation methods (such as the addition of vinegar), clean utensils used in preparation, short storage periods or by cool temperatures. If complete sterility is needed, the two most common methods are irradiation and the use of an autoclave, which resembles a pressure cooker.

There are several methods for investigating the level of hygiene in a sample of food, drinking water, equipment etc. Water samples can be filtrated through an extremely fine filter. This filter is then placed in a nutrient medium. Microorganisms on the filter then grow to form a visible colony. Harmful microorganisms can be detected in food by placing a sample in a nutrient broth designed to enrich the organisms in question. Various methods, such as selective media or PCR, can then be used for detection. The hygiene of hard surfaces, such as cooking pots, can be tested by touching them with a solid piece of nutrient medium and then allowing the microorganisms to grow on it.

There are no conditions where all microorganisms would grow, and therefore often several different methods are needed. For example, a food sample might be analyzed on three different nutrient mediums designed to indicate the presence of "total" bacteria (conditions where many, but not all, bacteria grow), molds (conditions where the growth of bacteria is prevented by e.g. antibiotics) and coliform bacteria (these indicate a sewage contamination).

Metallurgy

Metallurgy, science and technology of metals, including the extraction of metals from ores, the preparation of metals for use, and the study of the relationship between structures and properties of metals.

Metallurgical processes consist of two operations: concentration, separating a metal or metallic compound from the useless waste rock material, or gangue, which accompanies it in the ore; and refining, producing the metal in a pure or nearly pure state suitable for use. Three types of processes are employed both for concentration and refining: mechanical, chemical, and electrical. In most cases a combination of these methods is used.

One of the simplest methods of mechanical separation is gravity separation. This process is based on the difference in specific gravity between native metals and metallic minerals, and the other rock materials with which they are mixed. When crushed ore or ore concentrates are suspended either in water or an air blast, the heavier metal or metallic mineral particles fall to the bottom of the processing chamber, and the lighter gangue is blown or washed away. The prospector's technique of panning gold from gold-bearing sand, for example, is a small-scale gravity-separation process. Similarly, by virtue of its higher specific gravity, magnetite, a mineral of iron, may be separated from the gangue rock in which it occurs. Flotation is the most important present-day method of mechanical concentration. In its simplest form, flotation is a modified gravity process in which finely ground ore is mixed, usually with a liquid.

The metal or metallic mineral floats while the gangue sinks, although the reverse is true in some instances. In most modern flotation processes, the floating of either the metal or gangue is aided by an oil or other surface-active agent. By this means, comparatively heavy substances can be made to float on water. In one typical process, a finely ground ore containing copper sulfide is mixed with water, to which small amounts of oil, acid, or other so-called flotation reagents are added. When air is blown through this mixture, a froth is formed on the surface that has the property of mixing with the sulfide but not with the gangue.

The latter material settles, and the sulfide is collected from the froth. Use of the flotation process has made possible the exploitation of many ore deposits of low concentration, and even of the wastes from processing plants that used less efficient techniques. In some cases, by means of differential flotation, different minerals can be concentrated from one complex ore in a single process.

Ores, such as magnetite, that have marked magnetic properties are concentrated by means of electromagnets that attract the metal but do not attract the gangue. Electrostatic separation employs an electric field to separate minerals of different electrical properties by exploiting the attraction between unlike charges and the repulsion between like charges.

Chemical separation methods are, in general, the most important from the economic point of view. In present-day practice chemical separation often is used as a second stage after mechanical concentration. A greater tonnage of refined metal is obtained by smelting than by any other process. In smelting, the ore, or the concentrate from a mechanical separation process, is heated with a reducing agent and a flux to a high temperature.

The reducing agent combines with the oxygen in a metallic oxide, leaving pure metal; and the flux combines with the gangue to form a slag that is liquid at the smelting temperature and thus can be skimmed off or poured away from the metal. The production of pig iron in blast furnaces is an example of smelting, and the process is also used to extract copper, lead, nickel, and many other metals from their ores. Amalgamation is a metallurgical process that utilizes mercury to dissolve silver or gold to form an amalgam.

This process has been largely supplanted by the cyanide process, in which gold or silver is dissolved in solutions of sodium or potassium cyanide. Various types of aqueous solutions are employed in different leaching, or percolating, processes to dissolve metals from ores.

Metallic carbonates and sulfides are treated by roasting, heating to a temperature below the melting point of the metal. In the case of carbonates, carbon dioxide is driven off in the process, leaving a metallic oxide. When sulfides are roasted, the sulfur combines with the oxygen of the air to form gaseous sulfur dioxide, leaving metallic oxides, which are subsequently reduced by smelting.

Agglomeration of ore fines (fine particles) is accomplished by sintering or pelletizing. In the sintering process, fuel, water, air, and heat are used to fuse the ore fine into a porous mass. In pelletizing, moistened fine is formed into small pellets in the presence of limestone flux and then fired.

A number of other processes, of which pyrometallurgy (high-temperature metallurgy) and distillation are the most important, are employed in further refinement stages of a variety of metals. In the process of electrolysis the metal is deposited at the cathode from aqueous solutions or in an electrolytic furnace.

Copper, nickel, zinc, silver, and gold are several examples of metals that are refined by deposition from aqueous solutions. Aluminum, barium, calcium, magnesium, beryllium, potassium, and sodium are metals that are processed in electrolytic furnaces.

General Sequence of Operations

Occasionally, but rarely, metallic ores occur as practically pure compact masses, from which the accompanying matrix or "gangue" can be detached by hand and hammer. In most cases the "ore", as it comes out of the mine or quarry, is simply a mixture of ore proper and gangue, in which the latter not unfrequently predominates.

Hence it is generally necessary to purify the ore before the liberation of the metal is attempted. Most metallic ores are specifically heavier than the accompanying impurities and their purification is generally effected by reducing the crude ore to a fine enough powder to detach the metallic from the earthy part, and then washing away the latter by a current of water, as far as possible.

The majority of ores being chemical compounds, the extraction of their metals demands chemical treatment. The chemical operations involved may be classified as follows: I. *Fiery Operations. - The* ore, generally with some "flux," is exposed to the action of fire. The fire in most cases has a chemical, in addition to its physical, function. Moreover the furnace is designed so as to facilitate the action of the heat and furnace gases in the desired direction.

It is intended either to burn away certain components of the ore - in which case it must be so regulated as to contain a sufficient excess of unburned oxygen; or it is meant to deoxidize ("reduce") the ore,when the draught must be restricted so as to keep the ore constantly wrapped up in combustible flame gases (carbon monoxide, hydrogen, marsh-gas, &c.).

The majority of the chemical operations of metallurgy fall into this category, and in these processes other metal-reducing agents than those naturally contained in the fire (or blast) are only exceptionally employed.

Amalgamation

The ore by itself (if it is a reguline one), or with certain reagents (if it is not), is worked up with mercury so that the metal is obtained as an amalgam, which can be separated mechanically from the dross. The purified amalgam is distilled, when the mercury is recovered as a distillate while the metal remains.

Wet Processes

Strictly speaking, certain amalgamation methods fall under this head; but, in its ordinary acceptance, the term refers to processes in which the metal is extracted either from the natural ore, or from the ore after roasting or other preliminary treatment, by an acid or salt solution, and from this solution precipitated - generally in the reguline form - by some suitable reagent.

Few methods of metal extraction at once yield a pure product. What as a rule is obtained is a more or less impure metal, which requires to be "refined" to become fit for the market.

Chemical Operations

Amalgamation and wet-way processes have limited applications, being practically confined to copper, gold and silver. We therefore here confine ourselves, in the main, to pyro-chemical operations.

The method to be adopted for the extraction of a metal from its ore is determined chiefly, though not entirely, by the nature of the non-metallic component with which the metal is combined. The simplest case is that of the reguline ores where there is no nonmetallic element. The important case is that of gold.

Oxides, Hydrates, Carbonates and Silicates

All iron and tin ores proper fall under this heading, which, besides, comprises certain ores of copper, of lead and of zinc. The first step consists in subjecting the crude ore to a roasting or calcining process, the object of which is to remove the water and carbon dioxide, and burn away, to some extent at least, the sulphur, arsenic or organic matter.

The residue consists of an impure oxide of the respective metal, which in all cases is reduced by treatment with fuel at a high temperature. Should the metal be present as a silicate, lime must be added in the smelting to remove the silica and liberate the oxide.

The temperature required for the reduction of zinc lies above the boiling point of the metal; hence the mixture of ore and reducing agent (charcoal is generally used) must be heated in a retort combined with condensing apparatus. In all the other cases the reduction is effected in the fire itself, a tower-shaped blast furnace being preferably used.

The furnace is charged with alternate layers of fuel and ore and the whole kindled from below. The metallic oxide, partly by the direct action of the carbon with which it is in contact, but principally by that of the carbon monoxide produced in the lower strata from the oxygen of the blast and the hot carbon there, is reduced to the metallic state; the metal fuses and runs down, with the slag, to the bottom of the furnace, whence both are withdrawn by opening plug-holes.

Sulphides

Iron, copper, lead, zinc, mercury, silver and antimony very frequently present themselves in this state of combination, as components of a family of ores which may be divided into two sections:

- Such as substantially consist of simple sulphides, as iron pyrites (FeS_2), galena (PbS), zinc blende (ZnS), cinnabar (HgS); and
- Complex sulphides, such as the various kinds of sulphureous copper ores (all substantially compounds or mixtures of sulphides of copper and iron); bournonite, a complex sulphide of lead, antimony and copper; rothgiltigerz, sulphide of silver, antimony and arsenic; fahlerz, sulphides of arsenic and antimony, combined with sulphides of copper, silver, iron, zinc, mercury, silver; and mixtures of these and other sulphides with one another.

In treating a sulphureous ore, the first step as a rule is to subject it to oxidation by roasting it in a reverberatory or other furnace, which leads to the burning away of at least part of the arsenic and part of the sulphur.

The effect on the several individual metallic sulphides (supposing only one of these to be present) is as follows:

- Those of silver (Ag_2S) and mercury (HgS) yield sulphur dioxide gas and metal; in the case of silver, sulphate is formed at low temperatures. Metallic mercury, in the circumstances, goes off as a vapour, which is collected and condensed; silver remains as a regulus, but pure sulphide of silver is hardly ever worked.

- Sulphides of iron and zinc yield the oxides Fe_2O_3 and ZnO as final products, some basic sulphate being formed at the earlier stages, especially in the case of zinc. The oxides can be reduced by carbon.
- The sulphides of lead and copper yield, the former a mixture of oxide and normal sulphate, the latter one of oxide and basic sulphate. Sulphate of lead is stable at a red heat; sulphate of copper breaks up into oxide, sulphur dioxide and oxygen. In practice, neither oxidation process is ever pushed to the end; it is stopped as soon as the mixture of roasting-product and unchanged sulphide contains oxygen and sulphur in the ratio of 0 2: S. The access of air is then stopped and the whole heated to a higher temperature, when the whole of the sulphur and oxygen is eliminated. This method is largely utilized in the smelting of lead from galena and of copper from copper pyrites.
- Sulphide of antimony, when roasted in air, is converted into a kind of alloy of sulphide and oxide; the same holds for iron, only its oxysulphide is quite readily converted into the pure oxide Fe_2O_3 by further roasting. Oxysulphide of antimony, by suitable processes can be reduced to metal, but these processes are rarely used, because the same end is far more easily obtained by "precipitation," *i.e.* withdrawing the sulphur by fusion with metallic iron, forming metallic antimony and sulphide of iron. Both products fuse, but readily part, because fused antimony is far heavier than fused sulphide of iron. A precisely similar method is used occasionally for the reduction of lead from galena. Sulphide of lead, when fused together with metallic iron in the proportion of 2Fe: I PbS yields a regulus (= I Pb) and a "mat" Fe_2S, which, however, on cooling, decomposes into the ordinary sulphide FeS, and finely divided iron. What we have been explaining are

> special cases of a more general metallurgic proposition: Any one of the metals, copper, iron, tin, zinc, lead, silver, antimony, arsenic, in general, is capable of desulphurizing (at least partially) any of the others that follows it in the series just given, and it does so the more readily and completely the greater the number of intervening terms. Hence, supposing a complete mixture of these metals to be melted down under circumstances admitting of only a partial sulphuration of the whole, the copper has the best chance of passing into the "mat," while the arsenic is the first to be eliminated as such, or, in the presence of oxidants, as oxide.

SCIENTIFIC METHODS IN ECOLOGY

Systems analysis is an important techniqve of ecosystem research and environmental management. Watt has pointed out that ecological systems are characteristically dynamic and complex, usually involving interactions between many variables, and often displaying lag effects, cumulative effects, thresholds, and nonlinear causal relationships. Such complex phenomena cannot always be studied by traditional techniques of individual research and scholarship. Computer analysis and team research are often necessary.

Systems analysis is a logical scientific method which approaches complex phenomena in several stages of operation: (1) *systems measurement,* in which the objectives of the problems are outlined and accurate data are obtained on important variables which relate to these objectives; (2) *data analysis*, in which the relationships between variables are explored through appropriate statistical procedures, and those variables most important in regulating the system are determined, (3) *systems modelling*, in which functional or mathematical models are composed to provide a theor,etical basis for relating the variables, (4) *systems simulation*, in which variables are anipulated mathematically to evaluate the consequences of changes within the system, and (5) *systems optimization*, in which the best strategies for achieving the objectives are evaluated and selected.

This approach is basically similar to standard scientific procedure which involves description, classification, hypothesis formation, experimentation, and clinical tests or field trials. The particular characteristic of systems analysis, however, is that it can operate in very complex systems which require computerized data handling and do not lend themselves to direct experimentation. One can —a city, an ocean, or a range of mountains. Thus, mathematical modelling and computer simulation is sometimes the only feasible experimental approach in large-scale ecological research. Team research is also a usual component of systems analysis, for rarely can a single person possess all the skills necessary for the complete systems approach.

Systems analysis can be illustrated with the common problem of improving water quality in a badly polluted river. *Systems measurement* would first involve a statement of the objectives in water quality and river characteristics which are desired. These would be expressed in terms of physical characteristics (temperature, clarity, dissolved oxygen, nutrient levels, trace element concentrations, etc.), and biological characteristics (bacterial, algal, crustacean, insect, fish pop ulations, etc.) which are desired in the river. Systems measurement would then involve making a detailed inventory of existing conditions, so that accurate data would be obtained on the major physical and biotic features of the river in its present polluted condition. Systems measurement would finally involve the identification of the major influences on the stream. This would require knowledge of its watershed, weather patterns, land-use patterns, geologic formations, domestic inputs, industrial operations, and stream flow characteristics. Hence, the enormity of just stage one, systems measurement, becomes apparent. This stage in a relatively small river could easily take a team of 5 to 10 scientists several years to get baseline data and understand the prevailing situation in specific terms.

Stage two, *data analysis*, would involve computer and statistical analysis of relationships between variables. How do land-use patterns, industrial operations, and domestic inputs interact with topography, weather, and stream flow characteristics to influence the physical and biotic qualities of the'river? Some specific questions in this area would be: What are the sources of the nutrients? How do the nutrient levels influence the biotic communities? Are oxygen and temperature levels within satisfactory ranges If not, why not? Are toxic chemicals present in the stream. If so, what are their origins, their effects, and their fates? A great many questions of this type can be asked, and it is apparent that multivariate analyses, as well as other statistical procedures, must be utilized.

The third stage, *systems modelling*, would be undertaken when the investigators felt they had a lead on the origins and relationships of the important variables within the system. They could then propose a mathematical relationship between various factors influencing the prevailing conditions within the river. Data analyses might suggest, for example, that pesticide run-off from agricultural operations was poisoning the river and responsible for the absence of certain organisms. The analyses might also suggest that excessive nutrients from domestic sewage were creating high bacterial populations which reduced dissolved oxygen below satisfactory levels.

The fourth stage, *systems simulation*, would consist of computer runs with different variables modified. The model would then predict changes in other variables. For example, systems simulation would estimate and predict changes in the river if agricultural practices were altered, if sewage treatment plants were installed, or if industrial operations were curtailed. It becomes apparent that modern computer techniques are essential at several stages in systems analysis, especially in data analysis and in systems simulation. Ideally, an integrated computer technology program should be utilized throughout the entire systems research if possible, from data collection to systems optimization.

ECOLOGICAL GEOGRAPHY AND CONSERVATION

In the mid-nineteenth century, the field of ecological geography became established through the writings of George Perkins Marsh. One book published in 1864, *Man and Nature, or, Physical Geography as Modified by Human Action,* laid the foundation of ecological geography and conservation. As Stewart Udall pointed out in *The Quiet Crisis*, this book marked "the beginning of land wisdom in this country." Lewis Mumford described *Man and Nature* as "the fountainhead of the conservation movement."

Marsh's basic theme in *Man and Nature* was that man's economic progress has often disrupted the balance of nature to his own detriment. He clarified the reciprocal interaction of man and environment. Marsh traced the history of civilizations, particularly those in the Mediterranean area, in terms of physical geography, natural resources and land changes induced by man. He first called attention to the striking effects of deforestation and land scarring on erosion, agriculture, and water resources. He forced his readers to look upon man in a different light—not as a conqueeor but as a despoiler.

Marsh's greatest achievements were in scholarly fields. He became an accomplished linguist, a master of twenty languages, and he wrote several books of historical and linguistic scholarship. His Vermont background fostered a keen interest in landscape and nature, and he became intensely aware of man's influence on his environment. During his Mediterranean travels from 1848 to 1851, and his subsequent tenure in Italy beginning in 1861, he viewed the rocky and arid landscapes of the Middle East and the Mediterranean countries with an alarming new insight. He undertook historical investigations of former vegetation and water resources, and he documented carefully his conclusions on the role of man in shaping once fertile lands into present-day deserts.

Although *Man and Nature* was a financial success and was widely read upon publication in 1864, its influence on the conservation movement in the United States was slow in coming. In fact, the period of the 1870's and 1880's in this country witnessed unprecedented environmental exploitation. Forests were cut at a tremendous rate without regard for conservation, lands were cleared, plowed and abandoned with increasing speed. Devastation of animal resources accelerated, resulting in the decline of the American bison from more than 60 million prior to 1850 to a total United States population of less than 600 by 1890. The passenger pigeon was so ruthlessly hunted and its nesting habitat so effectively destroyed that it was virtually extinct by the end of the nineteenth century and the last zoo specimen died in Cincinnati in 1914.

Not for almost 40 years, in fact, were the conservation concerns expressed in *Man and Nature* turned into political realities through the activism of Gifford Pinchotand Theodore Roosevelt. Pinchot, later governor of Pennsylvania, was one of the first persons to advocate planned forest conservation in the United States. He became a member of the new National Forest Commission in 1896 and Chief of the Division of Forestry in 1898. Pinchot served as Chief of the Forest Service of the U.S. Department of Agriculture from 1905 to 1910 when he became president of the National Conservation Committee. In the same year he published an influential book entitled, *The Fight for Conservation*.

The greatest political momentum to the conservation movement in the United States came through the forceful efforts of Theodore Roosevelt. As a Dakota rancher from 1884 to 1886, Roosevelt became intensely interested in wildlife and natural habitat. He wrote profusely throughout this period, centering his writings on the history of the West and the benefits of wilderness. Twenty years later, as President of the United States, he emphasized environmental conservation as one of the country's most important domestic problems He added more acreage to the national forests than all presidents before and after. He regulated grazing and lumbering on national lands, and in 1908 he called the first White House conference on conservation. He worked closely with Pinchot in establishing the National Conservation Commission.

HEALTH GEOGRAPHY

Health geography is the application of geographical information, perspectives, and methods to the study of health, disease, and health care.

Overview

The study of health geography has been influenced by repositioning medical geography within the field of social geography due to a shift towards a social model in health care, rather than a medical model. This advocates for the redefinition of health and health care away from prevention and treatment of illness only to one of promoting well-being in general. Under this model, some previous illnesses (e.g., mental ill health) are recognized as behavior disturbances only, and other types of medicine (e.g., complementary or alternative medicine and traditional medicine) are studied by the medicine researchers, sometimes with the aid of health geographers without medical education. This shift changes the definition of care, no longer limiting it to spaces such as hospitals or doctor's offices. Also, the social model gives priority to the intimate encounters performed at non-traditional spaces of medicine and healthcare as well as to the individuals as health consumers.

This alternative methodological approach means that medical geography is broadened to incorporate philosophies such as Marxian political economy, structuralism, social interactionism, humanism, feminism and queer theory.

History

The relationship between space and health dates back to Hippocrates, who stated that "airs, waters, places" all played significant roles impacting human health and history. A classic piece of research in health geography was done in 1854 as a cholera outbreak gripped a neighborhood in London.

Death tolls rang around the clock and the people feared that they were being infected by vapors coming from the ground. John Snow predicted that if he could locate the source of the disease, it could be contained.

He drew maps demonstrating the homes of people who had died of cholera and the locations of water pumps. He found that one pump, the public pump on Broad Street, was central to most of the victims. He concluded that infected water from the pump was the culprit. He instructed the authorities to remove the handle to the pump, making it unusable. As a result, the number of new cholera cases decreased.

Areas of study

Health geography is considered to be divided into two distinct elements. The first of which is focused on geographies of disease and ill health, involving descriptive research quantifying disease frequencies and distributions, and analytic research concerned with finding what characteristics make an individual or population susceptible to disease.

This requires an understanding of epidemiology. The second component of health geography is the geography of health care, primarily facility location, accessibility, and utilization. This requires the use of spatial analysis and often borrows from behavioral economics.

Geographies of disease and ill health

Health geographers are concerned with the prevalence of different diseases along a range of spatial scales from a local to global view, and inspects the natural world, in all of its complexity, for correlations between diseases and locations.

This situates health geography alongside other geographical sub-disciplines that trace human-environment relations. Health geographers use modern spatial analysis tools to map the dispersion of various diseases, as individuals spread them amongst themselves, and across wider spaces as they migrate. Health geographers also consider all types of spaces as presenting health risks, from natural disasters, to interpersonal violence, stress, and other potential dangers.

Geography of health care provision

Although healthcare is a public good, it is not equally available to all individuals. Demand for public services is continuously increasing. People need advance knowledge and the latest prediction technology, that health geography offers. The latest example of such technology is Telemedicine. Many people in the United States are not able to access proper healthcare because of inequality in health insurance and the means to afford medical care.

Mobility and Disease Tracking

With the advent of mobile technology and its spread, it is now possible to track individual mobility.

By correlating the movement of individuals through tracking the devices using access towers or other tracking systems, it is now possible to determine and even control disease spread. While privacy laws question the legality of tracking individuals, the commercial mobile service providers are using covert techniques or obtaining government waivers to allow permission to track people.

10

Geography of Community Change

"Community is one of the most powerful words in the language, and perhaps because of this it is frequently misused. A profoundly emotive word, it is also a coercive one, and a key political buzzword in modern times. That community is being eroded in modern Britain is a matter of cross-party consensus, and it is also widely agreed that one of the state's roles is to devise means of counteracting the decline of communities."

It is refreshing to see a writer prepared to use 'community' and 'coercive' in the same sentence. Taunton reminds us that practically all urban architecture now attempts to force social solidarity into existence, and, by definition, condemns those who do not conform for daring to exercise their choice.

Unfortunately many of these attempts to coerce community into existence tend to repress or subvert the informal processes through which people interact of their own free will.

So why do so many influential people in the UK, the United States, and other countries of the New World, hold this 'consensus' that communities, like morality, are in decline, requiring government interventions to restore them to good health, within some reborn urban village?

In the past, communities were primarily place-based, if only because people could not travel very far or communicate over any great distance. But as civilizations have developed, this interaction between transport and communication has reshaped the prevailing structure and meaning of communities, as each reacts with each other. The printing presses of Renaissance Europe enabled the development of scientific and religious communities, as well as a host of "communities of ideas" both conservative and revolutionary.

Last century the establishment of national broadcast networks and television helped constitute national communities of listeners or viewers, which in turn reinforced the communities of "us" and "them" through the great global conflicts of that century.

The Internet has now created a whole new class of virtual communities or tribes. Many wage their tribal wars with considerable venom.

However, these internet tribes, too, simply build on the superior transportation technologies that have enabled us to physically flee to find more friendly groupings of associates, or to avoid the 'neighbours from hell'. Of course, place remains important to communities based on activity – people continue to visit their golf course, football field, church, beach, or shopping mall. Modern transport has gifted us with ready access to them all.

Similarly, communications technology plays an important role in communities of shared interests or ideas – the blog site, the book club, talk-back radio, and the specialist channels on cable TV or YouTube.

However, rigidly place-based communities can also be coercive traps.

In the late sixties I wrote a paper at U.C Berkeley drawing on surveys that showed that "neighboring" was more intensive in mobile-home parks than in most suburbs or inner city areas, precisely because the residents felt that if they fell out with their neighbors they could always move on. Neighboring is not without risk.

Similarly, people in camping grounds felt free to share coffee, drinks and dinners around the barbecue, precisely because they know they need not meet again. Many retirees have discovered the pleasures of the summer nomadic lifestyle spent driving from location to location in a well-appointed motor-home.

One retired couple (my American god-parents) were keen "rock-hounds" during the seventies and spent their summers driving their motor-home from one rock-rich territory to another, attending gatherings of rock-hounds along the way. They combined technological mobility, with place-based communities, and communities of common interests within the one retirement experience.

However, these contemporary communities, no matter how plentiful and rewarding, fail to meet the expectations of urban planners trapped within their general theory of architectural or spatial determinism. They remain convinced that urban form and places determine our behaviour. Yet in reality, our behaviour and preferences actually determine how and where we chose to live, work and play.

They may also be responding, in their reflexive way, to a genuine loss of sense of political community, a loss that may be more deeply felt that we think.

For the last forty or fifty years, through most of the New World jurisdictions, 'reform' of Local Government has meant 'amalgamation' on the presumption that 'bigger is better', probably because this coincided with the management theories of the sixties, which presumed conglomerates were the way of the future, and that all corporate mergers would benefit the shareholders and customers alike.

The track record of such local government 'reform' has given scant support to the theory. Forced amalgamations in particular have proved to be disastrous. And many of the voluntary ones – i.e. those driven from the bottom up – have fared little better.

These reform programs have generally been prepared to dilute or even ignore the traditional emphasis on 'community of interest' in favor of 'economies of scale' or the benefits of 'regional integrated planning.' In the end citizens have generally, and genuinely, lost contact with their Mayors and Councilors. They used to meet the Mayor in the street and have a chat about their concerns. Now they have to phone, leave voice messages and wait for the return call that never comes.

Political authority, now often housed in some distant place, is more remote than ever. You can't meet it, let alone beat it.

Citizens may know their ward councilor but their ward councilors explain they are always outvoted by a majority who has no interest in any ward but their own. This is why large councils are actually less effective at delivering satisfaction than small ones. A small council is likely to be serving a single community of interest. But if one neighborhood wants to build a municipal swimming pool, all those who live more than an hour's drive away understandably wonder why they should pay for a pool they will never use.

This bias towards larger and larger local bodies – enhanced by the rapid population growth in many peripheral areas and regional towns – has been given a massive boost in recent times by 'Smart Growth' planning theory. This approach necessitates large areas of regional governance so that people cannot escape from the planned densification that most independent areas would likely reject.

The Metro planners also often seek to extend their boundaries into the rural areas so as to prevent people and businesses locating where they prefer. Instead it is all determined by where the planners say people and business should go – for their own good, of course.

It may well be that when the central planners try to create "place-based communities" they are responding to a genuine problem, but have chosen the wrong tool-box to fix it. Community can not be imposed from above and large government is clearly the wrong way to nurture it.

A better approach may be to create a new system of local governance controlled by smaller, truly local councils, based on identifiable communities of interest, which are able to freely associate with other organizations if they believe it will provide services and infrastructure beyond their financial means. We should learn to define the services we need, and then match them to the appropriate organization, rather than trying to find the one or two magic sizes that can cope with all our needs.

We no longer need to accept being re-organized from above; the internet allows even smaller units access to sophisticated information.

We have a wonderful opportunity to take control of our destiny through a new world of local government in which the people themselves decide on their common communities of interest and set up novel and innovative joint-management entities where economic efficiency and common sense demand such arrangements.

COMMUNITY

A community is a social unit (a group of living things) with commonality such as norms, religion, values, customs, or identity. Communities may share a sense of place situated in a given geographical area (e.g. a country, village, town, or neighbourhood) or in virtual space through communication platforms.

Durable relations that extend beyond immediate genealogical ties also define a sense of community, important to their identity, practice, and roles in social institutions such as family, home, work, government, society, or humanity at large. Although communities are usually small relative to personal social ties, "community" may also refer to large group affiliations such as national communities, international communities, and virtual communities.

The English-language word "community" derives from the Old French *comuneté*, which comes from the Latin *communitas* "community", "public spirit" (from Latin *communis*, "shared in common").

Human communities may share intent, belief, resources, preferences, needs, and risks in common, affecting the identity of the participants and their degree of cohesiveness.

Perspectives of various disciplines

Archaeology

Archaeological studies of social communities use the term "community" in two ways, paralleling usage in other areas. The first is an informal definition of community as a place where people used to live. In this sense it is synonymous with the concept of an ancient settlement - whether a hamlet, village, town, or city. The second meaning resembles the usage of the term in other social sciences: a community is a group of people living near one another who interact socially. Social interaction on a small scale can be difficult to identify with archaeological data. Most reconstructions of social communities by archaeologists rely on the principle that social interaction in the past was conditioned by physical distance. Therefore, a small village settlement likely constituted a social community, and spatial subdivisions of cities and other large settlements may have formed communities. Archaeologists typically use similarities in material culture—from house types to styles of pottery—to reconstruct communities in the past. This classification method relies on the assumption that people or households will share more similarities in the types and styles of their material goods with other members of a social community than they will with outsiders.[5]

Ecology

In ecology, a community is an assemblage of populations of different species, interacting with one another. Community ecology is the branch of ecology that studies interactions between and among species. It considers how such interactions, along with interactions between species and the abiotic environment, affect community structure and species richness, diversity and patterns of abundance. Species interact in three ways: competition, predation and mutualism. Competition typically results in a double negative—that is both species lose in the interaction. Predation is a win/lose situation with one species winning. Mutualism, on the other hand, involves both species cooperating in some way, with both winning. The two main types of communities are major which are self-sustaining and self-regulating (such as a forest or a lake) and minor communities which rely on other communities (like fungi decomposing a log) and are the building blocks of major communities.

Key concepts

Gemeinschaft and Gesellschaft

In *Gemeinschaft und Gesellschaft* (1887), German sociologist Ferdinand Tönnies described two types of human association: *Gemeinschaft* (usually translated as "community") and *Gesellschaft* ("society" or "association"). Tönnies proposed the *Gemeinschaft–Gesellschaft* dichotomy as a way to think about social ties. No group is exclusively one or the other. *Gemeinschaft* stress personal social interactions, and the roles, values, and beliefs based on such interactions. *Gesellschaft* stress indirect interactions, impersonal roles, formal values, and beliefs based on such interactions.

Sense of community

In a seminal 1986 study, McMillan and Chavis identify four elements of "sense of community":

1. membership: feeling of belonging or of sharing a sense of personal relatedness,
2. influence: mattering, making a difference to a group and of the group mattering to its members
3. reinforcement: integration and fulfillment of needs,
4. shared emotional connection.

A "sense of community index *(SCI) was developed by Chavis and colleagues, and revised and adapted by others. Although originally designed to assess sense of community in neighborhoods, the index has been adapted for use in schools, the workplace, and a variety of types of communities.*

Studies conducted by the APPA indicate that young adults who feel a sense of belonging in a community, particularly small communities, develop fewer psychiatric and depressive disorders than those who do not have the feeling of love and belonging.

Socialization

The process of learning to adopt the behavior patterns of the community is called socialization. The most fertile time of socialization is usually the early stages of life, during which individuals develop the skills and knowledge and learn the roles necessary to function within their culture and social environment. For some psychologists, especially those in the psychodynamic tradition, the most important period of socialization is between the ages of one and ten. But socialization also includes adults moving into a significantly different environment, where they must learn a new set of behaviors.

Socialization is influenced primarily by the family, through which children first learn community norms. Other important influences include schools, peer groups, people, mass media, the workplace, and government. The degree to which the norms of a particular society or community are adopted determines one's willingness to engage with others. The norms of tolerance, reciprocity, and trust are important "habits of the heart," as de Tocqueville put it, in an individual's involvement in community.

DEFINITION OF COMMUNITY

In biological terms, a community is a group of interacting organisms sharing an environment. In human communities, intent, belief, resources, preferences, needs, risks, and a number of other conditions may be present and common, affecting the identity of the participants and their degree of cohesiveness.

In sociology, the concept of community has led to significant debate, and sociologists are yet to reach agreement on a definition of the term. There were ninety-four discrete definitions of the term by the mid-1950s. Traditionally a "community" has been defined as a group of interacting people living in a common location.

The word is often used to refer to a group that is organized around common values and is attributed with social cohesion within a shared geographical location, generally in social units larger than a household. The word can also refer to the national community or global community. The word "community" is derived from the Old French *communité* which is derived from the Latin *communitas*, a broad term for fellowship or organized society. Since the advent of the Internet, the concept of community no longer has geographical limitations, as people can now virtually gather in an online community and share common interests regardless of physical location.

Perspectives from various Disciplines

Gemeinschaft and Gesellschaft

German sociologist Ferdinand Tönnies distinguished between two types of human association: *Gemeinschaft* and *Gesellschaft*. In his 1887 work, *Gemeinschaft and Gesellschaft*, Tönnies argued that *Gemeinschaft* is perceived to be a tighter and more cohesive social entity, due to the presence of a "unity of will." He added that family and kinship were the perfect expressions of *Gemeinschaft*, but that other shared characteristics, such as place or belief, could also result in *Gemeinschaft*.

This paradigm of communal networks and shared social understanding has been applied to multiple cultures in many places throughout history. *Gesellschaft*, on the other hand, is a group in which the individuals who make up that group are motivated to take part in the group purely by self-interest. He also proposed that in the real world, no group was either pure *Gemeinschaft* or pure *Gesellschaft*, but, rather, a mixture of the two.

Social Capital

If community exists, both freedom and security may exist as well. The community then takes on a life of its own, as people become free enough to share and secure enough to get along. The sense of connectedness and formation of social networks comprise what has become known as social capital.

Social capital is defined by Robert D. Putnam as "the collective value of all social networks and the inclinations that arise from these networks to do things for each other." Social capital in action can be seen in all sorts of groups, including neighbours keeping an eye on each others' homes.

However, as Putnam notes in *Bowling Alone: The Collapse and Revival of American Community*, social capital has been falling in the United States. Putnam found that over the past 25 years, attendance at club meetings has fallen 58 per cent, family dinners are down 33 per cent, and having friends visit has fallen 45 per cent.

The same patterns are also evident in many other western countries. Western cultures are thus said to be losing the spirit of community that once were found in institutions including churches and community centers.

Sociologist Ray Oldenburg states in The Great Good Place that people need three places:

1. The home,
2. The office, and,
3. The community hangout or gathering place.

With this philosophy in mind, many grassroots efforts such as The Project for Public Spaces are being started to create this "Third Place" in communities. They are taking form in independent bookstores, coffeehouses, local pubs, and through many innovative means to create the social capital needed to foster the sense and spirit of community.

Anthropology

Community and its features are central to anthropological research.

Some of the ways community is addressed in anthropology include the following:

- *Cultural or Social Anthropology*: Cultural anthropology has traditionally looked at community through the lens of ethnographic fieldwork and ethnography continues to be an important methodology for study of modern communities. Other anthropological approaches that deal with various aspects of community include cross-cultural studies and the anthropology of religion. Cultures in modern society are also studied in the fields of urban anthropology, ethnic studies, ecological anthropology, and psychological anthropology. Since the 1990s, internet communities have increasingly been the subject of research in the emerging field of cyber anthropology.

- *Archaeology*: Archaeological studies of social communities. The term "community" is used in two ways in archaeology, paralleling usage in other areas. The first is an informal definition of community as a place where people used to live. In this sense it is synonymous with the concept of an ancient settlement, whether a hamlet, village, town, or city. The second meaning is similar to the usage of the term in other social sciences: a community is a group of people living near one another who interact socially. Social interaction on a small scale can be difficult to identify with archaeological data. Most reconstructions of social communities by archaeologists rely on the principle that social interaction is conditioned by physical distance. Therefore a small village settlement likely constituted a social community, and spatial subdivisions of cities and other large settlements may have formed communities. Archaeologists typically use similarities in material culture—from house types to styles of pottery—to reconstruct communities in the past. This is based on the assumption that people or households will share more similarities in the types and styles of their material goods with other members of a social community than they will with outsiders.

Social Philosophy

- *Communitarianism*: Communitarianism as a group of related but distinct philosophies began in the late 20th century, opposing classical liberalism and capitalism while advocating phenomena such as civil society. Not necessarily hostile to social liberalism, communitar-ianism rather has a different emphasis, shifting the focus of interest towards communities and societies and away from the individual. The question of priority, whether for the individual or community, must be determined in dealing with pressing ethical questions about a variety of social issues, such as health care, abortion, multiculturalism, and hate speech. Gad Barzilai has critically examined both liberalism and communitarianism and has developed the theory of critical communitarianism. Barzilai has explicated how non-ruling communities are constructing legal cultures while interacting with various facets of political power. Being venues of identity construction justifies collective protections of communities in law, while the boundaries with other communities, states, and global forces should be sensitive to preservation of various cultures. Gad Barzilai has accordingly offered how to protect human rights, individual rights, and multiculturalism in inter-communal context that allows to generating cultural relativism.

Business and Communications

- *Organizational Communication*: Effective comm-unication practices in group and organizational settings are very important to the formation and maintenance of communities. How ideas and values are communicated within communities are important to the induction of new members, the formulation of agendas, the selection of leaders and many other aspects. Organizational communication is the study of how people communicate within an organizational context and the influences and interactions within organizational structures. Group members depend on the flow of communication to establish their own identity within these structures and learn to function in the group setting. Although organizational communication, as a field of study, is usually geared towards companies and business groups, these may also be seen as communities. The principles of organizational communication can also be applied to other types of communities.

Ecology

In ecology, a community is an assemblage of populations of different species, interacting with one another. Community ecology is the branch of ecology that studies interactions between and among species. It considers how such interactions, along with interactions between species and the abiotic environment, affect community structure and species richness, diversity and patterns of abundance.

Species interact in three ways:

1. Competition,
2. Predation and
3. Mutualism.

Competition typically results in a double negative—that is both species lose in the interaction. Predation is a win/lose situation with one species winning. Mutualism, on the other hand, involves both species cooperating in some way, with both winning.

Interdisciplinary Perspectives

Socialization

The process of learning to adopt the behaviour patterns of the community is called socialization. The most fertile time of socialization is usually the early stages of life, during which individuals develop the skills and knowledge and learn the roles necessary to function within their culture and social environment.

For some psychologists, especially those in the psychodynamic tradition, the most important period of socialization is between the ages of one and ten. But socialization also includes adults moving into a significantly different environment, where they must learn a new set of behaviours.

Socialization is influenced primarily by the family, through which children first learn community norms. Other important influences include school, peer groups, people, schools, mass media, the workplace, and government. The degree to which the norms of a particular society or community are adopted determines one's willingness to engage with others. The norms of tolerance, reciprocity, and trust are important "habits of the heart," as de Tocqueville put it, in an individual's involvement in community.

Community Development

Community development, often linked with Community Work or Community Planning, is often formally conducted by non-government organizations, universities or government agencies to progress the social well-being of local, regional and, sometimes, national communities.

Less formal efforts, called community building or community organizing, seek to empower individuals and groups of people by providing them with the skills they need to effect change in their own communities. These skills often assist in building political power through the formation of large social groups working for a common agenda. Community development practitioners must understand both how to work with individuals and how to affect communities' positions within the context of larger social institutions.

Formal programme conducted by universities are often used to build a knowledge base to drive curricula in sociology and community studies. The General Social Survey from the National Opinion Research Center at the University of Chicago and the Saguaro Seminar at the John F. Kennedy School of Government at Harvard University are examples of national community development in the United States. In The United Kingdom, Oxford University has led in providing extensive research in the field through its *Community Development Journal*, used worldwide by sociologists and community development practitioners. At the intersection between community *development* and community *building* are a number of programme and organizations with community development tools. One example of this is the programme of the Asset Based Community Development Institute of Northwestern University. The institute makes available downloadable tools to assess community assets and make connections between non-profit groups and other organizations that can help in community building. The Institute focuses on helping communities develop by "mobilizing neighbourhood assets"—building from the inside out rather than the outside in.

Community Building and Organizing

- In *the Different Drum: Community-Making and Peace,* Scott Peck argues that the almost accidental sense of community that exists at times of crisis can be consciously built. Peck believes that conscious community building is a process of deliberate design based on the knowledge and application of certain rules.

  He states that this process goes through four stages:

1. *Chaos*: When people move beyond the inauthen-ticity of pseudo-community and feel safe enough to present their "shadow" selves. This stage places great demands upon the facilitator for greater leadership and organization, but Peck believes that "organizations are not communities", and this pressure should be resisted.
2. *Emptiness*: This stage moves beyond the attempts to fix, heal and convert of the chaos stage, when all people become capable of acknowledging their own woundedness and brokenness, common to us all as human beings. Out of this emptiness comes
3. *Pseudo Community*: Where participants are "nice with each other", playing-safe, and presenting what they feel is the most favourable sides of their personalities.
4. *True Community*: the process of deep respect and true listening for the needs of the other people in this community. This stage Peck believes can only be described as "glory" and reflects a deep yearning in every human soul for compassionate understan-ding from one's fellows.

More recently Peck remarked that building a sense of community is easy but maintaining this sense of community is difficult in the modern world. Community building can use a wide variety of practices, ranging from simple events such as potlucks and small book clubs to larger–scale efforts such as mass festivals and construction projects that involve local participants rather than outside contractors. Community building that is geared towards citizen action is usually termed "community organizing."

In these cases, organized community groups seek accountability from elected officials and increased direct representation within decision-making bodies. Where good-faith negotiations fail, these constituency-led organizations seek to pressure the decision-makers through a variety of means, including picketing, boycotting, sit-ins, petitioning, and electoral politics. The ARISE Detroit! coalition and the Toronto Public Space Committee are examples of activist networks committed to shielding local communities from government and corporate domination and inordinate influence.

Community organizing is sometimes focused on more than just resolving specific issues. Organizing often means building a widely accessible power structure, often with the end goal of distributing power equally throughout the community. Community organizers generally seek to build groups that are open and democratic in governance. Such groups facilitate and encourage consensus decision-making with a focus on the general health of the community rather than a specific interest group. The three basic types of community organizing are grassroots organizing, coalition building, and "institution-based community organizing,".

Community Currencies

Some communities have developed their own "Local Exchange Trading Systems" and local currencies, such as the Ithaca Hours system, to encourage economic growth and an enhanced sense of community. Community Currencies have recently proven valuable in meeting the needs of people living in various South American nations, particularly Argentina, that recently suffered as a result of the collapse of the Argentinian national currency.

Community Service

Community service is usually performed in connection with a nonprofit organization, but it may also be undertaken under the auspices of government, one or more businesses, or by individuals. It is typically unpaid and voluntary. However, it can be part of alternative sentencing approaches in a justice system and it can be required by educational institutions.

Types of Community

A number of ways to categorize types of community have been proposed; one such breakdown is:

- *Geographic Communities*: Range from the local neighbourhood, suburb, village, town or city, region, nation or even the planet as a whole. These refer to communities of *location*.
- *Communities of Culture*: Range from the local clique, sub-culture, ethnic group, religious, multicultural or pluralistic civilization, or the global community cultures of today. They may be included as *communities of need* or *identity*, such as disabled persons, or frail aged people.
- *Community Organizations*: Range from informal family or kinship networks, to more formal incorporated associations, political decision making structures, economic enterprises, or professional associations at a small, national or international scale.

Communities are nested; one community can contain another— for example a geographic community may contain a number of ethnic communities.

Location

Possibly the most common usage of the word *"community"* indicates a large group living in close proximity.

Examples of local community include:

- A municipality is an administrative local area generally composed of a clearly defined territory and commonly referring to a town or village. Although large cities are also municipalities, they are often thought of as a collection of communities, due to their diversity.
- A neighbourhood is a geographically localized community, often within a larger city or suburb.
- A planned community is one that was designed from scratch and grew up more or less following the plan. Several of the world's capital cities are planned cities, notably

Washington, D.C., in the United States, Canberra in Australia, and Brasília in Brazil. It was also common during the European colonization of the Americas to build according to a plan either on fresh ground or on the ruins of earlier Amerindian cities.

Identity

In some contexts, *"community"* indicates a group of people with a common identity other than location. Members often interact regularly.

Common examples in everyday usage include:

- A "professional community" is a group of people with the same or related occupations. Some of those members may join a professional society, making a more defined and formalized group. These are also sometimes known as communities of practice.
- A virtual community is a group of people primarily or initially communicating or interacting with each other by means of information technologies, typically over the Internet, rather than in person. These may be either communities of interest, practice or communion. Research interest is evolving in the motivations for contributing to online communities.

Overlaps

Some communities share both location and other attributes.

Members choose to live near each other because of one or more common interests:

- A retirement community is designated and at least usually designed for retirees and seniors—often restricted to those over a certain age, such as 56. It differs from a retirement home, which is a single building or small complex, by having a number of autonomous households.
- An intentional community is a deliberate residential community with a much higher degree of social communication than other

communities. The members of an intentional community typically hold a common social, political or spiritual vision and share responsibilities and resources. Intentional communities include Amish villages, ashrams, cohousing, communes, ecovillages, housing cooperatives, kibbutzim, and land trusts.

Special Nature of Human Community

Definitions of community as "organisms inhabiting a common environment and interacting with one another," while scientifically accurate, do not convey the richness, diversity and complexity of human communities. Their classification, likewise is almost never precise. Untidy as it may be, community is vital for humans.

M. Scott Peck expresses this in the following way:

- "There can be no vulnerability without risk; there can be no community without vulnerability; there can be no peace, and ultimately no life, without community."

COMMUNITY DEVELOPMENT

Community development is often linked with community work or community planning, and may involve stakeholders, foundations, governments, or contracted entities including non-government organisations (NGOs), universities or government agencies to progress the social well-being of local, regional and, sometimes, national communities. More grassroots efforts, called community building or community organizing, seek to empower individuals and groups of people by providing them with the skills they need to effect change in their own communities. These skills often assist in building political power through the formation of large social groups working for a common agenda. Community development practitioners must understand both how to work with individuals and how to affect communities' positions within the context of larger social institutions. Public administrators, in contrast, need to understand community development in the context of rural and urban development, housing and economic development, and community, organizational and business development.

Formal accredited programs conducted by universities, as part of degree granting institutions, are often used to build a knowledge base to drive curricula in public administration, sociology and community studies. The General Social Survey from the National Opinion Research Center at the University of Chicago and the Saguaro Seminar at the John F. Kennedy School of Government at Harvard University are examples of national community development in the United States. The Maxwell School of Citizenship and Public Affairs at Syracuse University in New York State offers core courses in community and economic development, and in areas ranging from non-profit development to US budgeting (federal to local, community funds). In the United Kingdom, Oxford University has led in providing extensive research in the field through its *Community Development Journal*, used worldwide by sociologists and community development practitioners.

At the intersection between community *development* and community *building* are a number of programs and organizations with community development tools. One example of this is the program of the Asset Based Community Development Institute of Northwestern University. The institute makes available downloadable tools to assess community assets and make connections between non-profit groups and other organizations that can help in community building. The Institute focuses on helping communities develop by "mobilizing neighborhood assets" – building from the inside out rather than the outside in. In the disability field, community building was prevalent in the 1980s and 1990s with roots in John McKnight's approaches.

Community building and organizing

In *The Different Drum: Community-Making and Peace* (1987) Scott Peck argues that the almost accidental sense of community that exists at times of crisis can be consciously built. Peck believes that conscious community building is a process of deliberate design based on the knowledge and application of certain rules. He states that this process goes through four stages:

1. Pseudocommunity: When people first come together, they try to be "nice" and present what they feel are their most personable and friendly characteristics.
2. Chaos: People move beyond the inauthenticity of pseudo-community and feel safe enough to present their "shadow" selves.
3. Emptiness: Moves beyond the attempts to fix, heal and convert of the chaos stage, when all people become capable of acknowledging their own woundedness and brokenness, common to human beings.
4. True community: Deep respect and true listening for the needs of the other people in this community.

In 1991, Peck remarked that building a sense of community is easy but maintaining this sense of community is difficult in the modern world.

The three basic types of community organizing are grassroots organizing, coalition building, and "institution-based community organizing," (also called "broad-based community organizing," an example of which is faith-based community organizing, or Congregation-based Community Organizing).

Community building can use a wide variety of practices, ranging from simple events (e.g., potlucks, small book clubs) to larger-scale efforts (e.g., mass festivals, construction projects that involve local participants rather than outside contractors).

Community building that is geared toward citizen action is usually termed "community organizing." In these cases, organized community groups seek accountability from elected officials and increased direct representation within decision-making bodies. Where good-faith negotiations fail, these constituency-led organizations seek to pressure the decision-makers through a variety of means, including picketing, boycotting, sit-ins, petitioning, and electoral politics.

Community organizing can focus on more than just resolving specific issues. Organizing often means building a widely accessible power structure, often with the end goal of distributing power equally throughout the community. Community organizers generally seek to build groups that are open and democratic in governance. Such groups facilitate and encourage consensus decision-making with a focus on the general health of the community rather than a specific interest group.

If communities are developed based on something they share in common, whether location or values, then one challenge for developing communities is how to incorporate individuality and differences. Rebekah Nathan suggests in her book, *My Freshman Year*, we are drawn to developing communities totally based on sameness, despite stated commitments to diversity, such as those found on university websites.

Community currencies

Some communities have developed their own local exchange trading systems (LETS) and local currencies, such as the Ithaca Hours system, to encourage economic growth and an enhanced sense of community. Community currencies have recently proven valuable in meeting the needs of people living in various South American nations, particularly Argentina, that recently suffered as a result of the collapse of the Argentinian national currency.

TYPES OF COMMUNITY

A number of ways to categorize types of community have been proposed. One such breakdown is as follows:

1. Location-based Communities: range from the local neighbourhood, suburb, village, town or city, region, nation or even the planet as a whole. These are also called communities of place.
2. Identity-based Communities: range from the local clique, sub-culture, ethnic group, religious, multicultural or pluralistic civilisation, or the global community cultures of today. They may be included as *communities of need* or *identity*, such as disabled persons, or frail aged people.
3. Organizationally based Communities: range from communities organized informally around family or

network-based guilds and associations to more formal incorporated associations, political decision making structures, economic enterprises, or professional associations at a small, national or international scale.

The usual categorizations of community relations have a number of problems: (1) they tend to give the impression that a particular community can be defined as just this kind or another; (2) they tend to conflate modern and customary community relations; (3) they tend to take sociological categories such as ethnicity or race as given, forgetting that different ethnically defined persons live in different kinds of communities —grounded, interest-based, diasporic, etc. In response to these problems, Paul James and his colleagues have developed a taxonomy that maps community relations, and recognizes that actual communities can be characterized by different kinds of relations at the same time:

1. Grounded community relations. This involves enduring attachment to particular places and particular people. It is the dominant form taken by customary and tribal communities. In these kinds of communities, the land is fundamental to identity.
2. Life-style community relations. This involves giving primacy to communities coming together around particular chosen ways of life, such as morally charged or interest-based relations or just living or working in the same location. Hence the following sub-forms:
    1. community-life as morally bounded, a form taken by many traditional faith-based communities.
    2. community-life as interest-based, including sporting, leisure-based and business communities which come together for regular moments of engagement.
    3. community-life as proximately-related, where neighbourhood or commonality of association forms a community of convenience, or a community of place.
3. Projected community relations. This is where a community is self-consciously treated as an entity to be projected and

> re-created. It can be projected as through thin advertising slogan, for example gated community, or can take the form of ongoing associations of people who seek political integration, communities of practice based on professional projects, associative communities which seek to enhance and support individual creativity, autonomy and mutuality. A nation is one of the largest forms of projected or imagined community.

In these terms, communities can be nested and/or intersecting; one community can contain another—for example a location-based community may contain a number of ethnic communities. Both lists above can used in a cross-cutting matrix in relation to each other.

Internet communities

In general, virtual communities value knowledge and information as currency or social resource. What differentiates virtual communities from their physical counterparts is the extent and impact of "weak ties," which are the relationships acquaintances or strangers form to acquire information through online networks. Relationships among members in a virtual community tend to focus on information exchange about specific topics. A survey conducted by Pew Internet and The American Life Project in 2001 found those involved in entertainment, professional, and sports virtual groups focused their activities on obtaining information.

An epidemic of bullying and harassment has arisen from the exchange of information between strangers, especially among teenagers, in virtual communities. Despite attempts to implement anti-bullying policies, Sheri Bauman, professor of counselling at the University of Arizona, claims the "most effective strategies to prevent bullying" may cost companies revenue.

11

Environment and Population

POPULATION & THE ENVIRONMENT

The combination of increasing levels of population and consumption is changing the planet's ecosystems at an unprecedented rate and scale, with rates of biodiversity loss posing a major threat to human well-being. Population dynamics, including population growth, density, urbanisation and migration, are important underlying causes of biodiversity loss, with human demands for food, energy, land and other natural resources placing ecosystems under increasing stress.

Population growth and density are often particularly high in areas where there is the greatest biodiversity, and therefore the greatest threat of biodiversity loss. While conservationists acknowledge the role of human population dynamics as an underlying driver of declining levels of biodiversity, few conservation strategies directly address the issues which lead to patterns of population growth, such as barriers to family planning information, rights and services.

Population, Health & Environment programmes

By improving reproductive health rights, and services, and therefore responding to the unmet need, we can significantly reduce unintended pregnancies. This lessens the risk of environmental impacts and enhances the potential for societal resilience to climate change, water scarcity, food insecurity, the loss of biological diversity, and related threats. Indeed, the World Health Organization has said, "Family planning is key to slowing unsustainable population growth and the resulting negative impacts on the economy, environment, and national and regional development efforts." Population and the environment should not be considered as two separate issues, but as interrelated issues, with the conservation sector responding in an integrated, rights-based manner, together with the health sector.

Population, Health & Environment (PHE) programmes take a pragmatic and holistic approach to these interconnected issues, by integrating reproductive health actions with conservation actions promoting sustainable livelihoods. PHE programmes are particularly appropriate for the many marginalised rural communities relying directly on healthy ecosystems for their food and water security, livelihoods and building materials. Integrating reproductive health and conservation livelihood actions creates synergies improving both community and ecosystem health. When projects address the interactions between people, their health, and their environment, it makes conservation programmes more effective, sustainable, and cost effective than traditional vertical programmes. The Network's project, A Re Itireleng, is one such PHE project which the Network uses in its advocacy actions.

POPULATION DISTRIBUTION

The ways in which populations are spread across Earth has an effect on the environment. Developing countries tend to have higher birth rates due to poverty and lower access to family planning and education, while developed countries have lower birth rates. In 2015, 80 per cent of the world's population live in less-developed nations. These faster-growing populations can add pressure to local environments.

Globally, in almost every country, humans are also becoming more urbanised. In 1960 less than one third of the world's population lived in cities.

While many enthusiasts for centralisation and urbanisation argue this allows for resources to be used more efficiently, in developing countries this mass movement of people heading towards the cities in search of employment and opportunity often outstrips the pace of development, leading to slums, poor (if any) environmental regulation, and higher levels of centralised pollution. Even in developed nations, more people are moving to the cities than ever before. The pressure placed on growing cities and their resources such as water, energy and food due to continuing growth includes pollution from additional cars, heaters and other modern luxuries, which can cause a range of localised environmental problems.

Humans have always moved around the world. However, government policies, conflict or environmental crises can enhance these migrations, often causing short or long-term environmental damage. For example, since 2011 conditions in the Middle East have seen population transfer (also known as unplanned migration) result in several million refugees fleeing countries including Syria, Iraq and Afghanistan. The sudden development of often huge refugee camps can affect water supplies, cause land damage (such as felling of trees for fuel) or pollute environments (lack of sewerage systems).

Population composition

The composition of a population can also affect the surrounding environment. At present, the global population has both the largest proportion of young people (under 24) and the largest percentage of elderly people in history. As young people are more likely to migrate, this leads to intensified urban environmental concerns, as listed above.

Life expectancy has increased by approximately 20 years since 1960. While this is a triumph for mankind, and certainly a good thing for the individual, from the planet's point of view it is just another body that is continuing to consume resources and produce waste for around 40 per cent longer than in the past.

Ageing populations are another element to the multi-faceted implications of demographic population change, and pose challenges of their own. For example between 1970 and 2006, Japan's proportion of people over 65 grew from 7 per cent to more than 20 per cent of its population. This has huge implications on the workforce, as well as government spending on pensions and health care.

Population income is also an important consideration. The uneven distribution of income results in pressure on the environment from both the lowest and highest income levels. In order to simply survive, many of the world's poorest people partake in unsustainable levels of resource use, for example burning rubbish, tyres or plastics for fuel. They may also be forced to deplete scarce natural resources, such as forests or animal populations, to feed their families. On the other end of the spectrum, those with the highest incomes consume disproportionately large levels of resources through the cars they drive, the homes they live in and the lifestyle choices they make.

On a country-wide level, economic development and environmental damage are also linked. The least developed nations tend to have lower levels of industrial activity, resulting in lower levels of environmental damage. The most developed countries have found ways of improving technology and energy efficiency to reduce their environmental impact while retaining high levels of production. It is the countries in between—those that are developing and experiencing intense resource consumption (which may be driven by demand from developed countries)—that are often the location of the most environmental damage.

Population consumption

While poverty and environmental degradation are closely interrelated, it is the unsustainable patterns of consumption and production, primarily in developed nations, that are of even greater concern.

It's not often that those in developed countries stop and consider our own levels of consumption. For many, particularly in industrialised countries, the consumption of goods and resources is just a part of our lives and culture, promoted not only by advertisers but also by governments wanting to continually grow their economy. Culturally, it is considered a normal part of life to shop, buy and consume, to continually strive to own a bigger home or a faster car, all frequently promoted as signs of success. It may be fine to participate in consumer culture and to value material possessions, but in excess it is harming both the planet and our emotional wellbeing.

The environmental impact of all this consumption is huge. The mass production of goods, many of them unnecessary for a comfortable life, is using large amounts of energy, creating excess pollution, and generating huge amounts of waste.

To complicate matters, environmental impacts of high levels of consumption are not confined to the local area or even country. For example, the use of fossil fuels for energy (to drive our bigger cars, heat and cool our bigger houses) has an impact on global CO_2 levels and resulting environmental effects. Similarly, richer countries are also able to rely on resource and/or waste-intensive imports being produced in poorer countries. This enables them to enjoy the products without having to deal with the immediate impacts of the factories or pollution that went in to creating them.

On a global scale, not all humans are equally responsible for environmental harm. Consumption patterns and resource use are very high in some parts of the world, while in others—often in countries with far more people—they are low, and the basic needs of whole populations are not being met. A study undertaken in 2009 showed that the countries with the fastest population growth also had the slowest increases in carbon emissions. The reverse was also true—for example the population of North America grew only 4 per cent between 1980 and 2005, while its carbon emissions grew by 14 per cent.

Individuals living in developed countries have, in general, a much bigger ecological footprint than those living in the developing world. The ecological footprint is a standardised measure of how much productive land and water is needed to produce the resources that are consumed, and to absorb the wastes produced by a person or group of people.

Today humanity uses the equivalent of 1.5 planets to provide the resources we use and absorb our waste. This means it now takes the Earth one year and six months to regenerate what we use in a year. Global Footprint Network

When Australian consumption is viewed from a global perspective, we leave an exceptionally large 'ecological footprint'—one of the largest in the world. While the average global footprint is 2.7 global hectares, in 2014 Australia's ecological footprint was calculated at 6.7 global hectares per person (this large number is mostly due to our carbon emissions). To put this in perspective, if the rest of world lived like we do in Australia, we would need the equivalent of 3.6 Earths to meet the demand.

Similarly, an American has an ecological footprint almost 9 times larger than an Indian—so while the population of India far exceeds that of the United States, in terms of environmental damage, it is the American consumption of resources that is causing the higher level of damage to the planet.

DEMOGRAPHIC TRANSITION

Demographic transition (DT) refers to the transition from high birth and death rates to low birth and death rates as a country develops from a pre-industrial to an industrialized economic system. This is typically demonstrated through ademographic transition model (DTM). The theory is based on an interpretation of demographic history developed in 1929 by the American demographer Warren Thompson (1887–1973). Thompson observed changes, or transitions, in birth and death rates in industrialized societies over the previous 200 years. Most developed countries are in stage 3 or 4 of the model; the majority of developing countries have reached stage 2 or stage 3. The major (relative) exceptions are some poor countries, mainly in sub-Saharan Africa and some Middle Eastern countries, which are poor or affected by government policy or civil strife, notably Pakistan, Palestinian Territories, Yemen and Afghanistan.

Although this model predicts ever decreasing fertility rates, recent data show that beyond a certain level of development fertility rates increase again. A correlation matching the demographic transition has been established; however, it is not certain whether industrialization and higher incomes lead to lower population or if lower populations lead to industrialization and higher incomes. Incountries that are now developed this demographic transition began in the 18th century and continues today. In less developed countries, this demographic transition started later and is still at an earlier stage.

Summary of the Theory

The transition involves four stages, or possibly five.

- In stage one, pre-industrial society, death rates and birth rates are high and roughly in balance. All human populations are believed to have had this balance until the late 18th century, when this balance ended in Western Europe. In fact, growth rates were less than 0.05% at least since the Agricultural Revolution over 10,000 years ago. Birth and death rates both tend to be very high in this stage. Because both rates are approximately in balance, population growth is typically very slow in stage one.
- In stage two, that of a developing country, the death rates drop rapidly due to improvements in food supply and sanitation, which increase life spans and reduce disease. The improvements specific to food supply typically include selective breeding and crop rotation and farming techniques. Other improvements generally include access to technology, basic healthcare, and education. For example, numerous improvements in public health reduce mortality, especially childhood mortality. Prior to the mid-20th century, these improvements in public health were primarily in the areas of food handling, water supply, sewage, and personal hygiene. One of the variables often cited is the increase in female literacy combined with public health education programs which emerged in the late 19th and early 20th centuries. In Europe, the death rate decline started in the late 18th century in northwestern Europe

and spread to the south and east over approximately the next 100 years. Without a corresponding fall in birth rates this produces animbalance, and the countries in this stage experience a large increase in population.

- In stage three, birth rates fall due to access to contraception, increases in wages, urbanization, a reduction in subsistence agriculture, an increase in the status and education of women, a reduction in the value of children's work, an increase in parental investment in the education of children and other social changes. Population growth begins to level off. The birth rate decline in developed countries started in the late 19th century in northern Europe. While improvements in contraception do play a role in birth rate decline, it should be noted that contraceptives were not generally available nor widely used in the 19th century and as a result likely did not play a significant role in the decline then. It is important to note that birth rate decline is caused also by a transition in values; not just because of the availability of contraceptives.
- During stage four there are both low birth rates and low death rates. Birth rates may drop to well below replacement level as has happened in countries like Germany, Italy, and Japan, leading to a shrinking population, a threat to many industries that rely on population growth. As the large group born during stage two ages, it creates an economic burden on the shrinking working population. Death rates may remain consistently low or increase slightly due to increases in lifestyle diseases due to low exercise levels and high obesity and an aging population in developed countries. By the late 20th century, birth rates and death rates in developed countries leveled off at lower rates.

As with all models, this is an idealized picture of population change in these countries. The model is a generalization that applies to these countries as a group and may not accurately describe all individual cases. The extent to which it applies to less-developed societies today remains to be seen. Many countries such as China, Brazil and Thailandhave passed through the Demographic Transition Model (DTM) very quickly due to fast social and economic change. Some countries, particularly African countries, appear to be stalled in the second stage due to stagnant development and the effect of AIDS.

Stage One

In pre-industrial society, death rates and birth rates were both high and fluctuated rapidly according to natural events, such as drought and disease, to produce a relatively constant and young population. Family planning and contraception were virtually nonexistent; therefore, birth rates were essentially only limited by the ability of women to bear children. Emigration depressed death rates in some special cases (for example, Europe and particularly the Eastern United States during the 19th century), but, overall, death rates tended to match birth rates, often exceeding 40 per 1000 per year.

Children contributed to the economy of the household from an early age by carrying water, firewood, and messages, caring for younger siblings, sweeping, washing dishes, preparing food, and working in the fields. Raising a child cost little more than feeding him or her; there were no education or entertainment expenses. Thus, the total cost of raising children barely exceeded their contribution to the household. In addition, as they became adults they become a major input to the family business, mainly farming, and were the primary form of insurance for adults in old age. In India, an adult son was all that prevented a widow from falling into destitution. While death rates remained high there was no question as to the need for children, even if the means to prevent them had existed.

During this stage, the society evolves in accordance with Malthusian paradigm, with population essentially determined by the food supply. Any fluctuations in food supply (either positive, for example, due to technology improvements, or negative, due to droughts and pest invasions) tend to translate directly into population fluctuations. Famines resulting in significant mortality are frequent. Overall, the population dynamics during stage one is highly reminiscent of that commonly observed in animals.

Stage Two

This stage leads to a fall in death rates and an increase in population. The changes leading to this stage in Europe were initiated in the Agricultural Revolution of the 18th century and were initially quite slow. In the 20th century, the falls in death rates in developing countries tended to be substantially faster. Countries in this stage include Yemen, Afghanistan, the Palestinian territories, Bhutan and Laos and much of Sub-Saharan Africa (but do not include South Africa, Zimbabwe, Botswana, Swaziland, Lesotho, Namibia, Kenya and Ghana, which have begun to move into stage 3).

The decline in the death rate is due initially to two factors:

- First, improvements in the food supply brought about by higher yields in agricultural practices and better transportation prevent death due to starvation and lack of water. Agricultural improvements included crop rotation, selective breeding, and seed drill technology.
- Second, significant improvements in public health reduce mortality, particularly in childhood. These are not so many medical breakthroughs (Europe passed through stage two before the advances of the mid-20th century, although there was significant medical progress in the 19th century, such as the development of vaccination) as they are improvements in water supply, sewerage, food handling, and general personal hygiene following from growing scientific knowledge of the causes of disease and the improved education and social status of mothers.

A consequence of the decline in mortality in Stage Two is an increasingly rapid rise in population growth (a "population explosion") as the gap between deaths and births grows wider.

Note that this growth is not due to an increase in fertility (or birth rates) but to a decline in deaths. This change in population occurred in north-western Europe during the 19th century due to the Industrial Revolution. During the second half of the 20th century less-developed countries entered Stage Two, creating the worldwide population explosion that has demographers concerned today. In this stage of DT, countries are vulnerable to become failed states in the absence of progressive governments.

Another characteristic of Stage Two of the demographic transition is a change in the age structure of the population. In Stage One, the majority of deaths are concentrated in the first 5–10 years of life. Therefore, more than anything else, the decline in death rates in Stage Two entails the increasing survival of children and a growing population. Hence, the age structure of the population becomes increasingly youthful and more of these children enter the reproductive cycle of their lives while maintaining the high fertility rates of their parents. The bottom of the "age pyramid" widens first, accelerating population growth. The age structure of such a population is illustrated by using an example from the Third World today.

Stage Three

Stage Three moves the population towards stability through a decline in the birth rate. Several factors contribute to this eventual decline, although some of them remain speculative:

- In rural areas continued decline in childhood death means that at some point parents realize they need not require so many children to be born to ensure a comfortable old age. As childhood death continues to fall and incomes increase parents can become increasingly confident that fewer children will suffice to help in family business and care for them in old age.
- Increasing urbanization changes the traditional values placed upon fertility and the value of children in rural society. Urban living also raises the cost of dependent children to a family. A recent theory suggests that urbanization also contributes to reducing the birth rate because it disrupts optimal mating patterns. A 2008 study in Iceland found that the most fecund marriages are

between distant cousins. Genetic incompatibilities inherent in more distant outbreeding makes reproduction harder.

- In both rural and urban areas, the cost of children to parents is exacerbated by the introduction of compulsory education acts and the increased need to educate children so they can take up a respected position in society. Children are increasingly prohibited under law from working outside the household and make an increasingly limited contribution to the household, as school children are increasingly exempted from the expectation of making a significant contribution to domestic work. Even in equatorial Africa, children now need to be clothed, and may even require school uniforms. Parents begin to consider it a duty to buy children books and toys. Partly due to education and access to family planning, people begin to reassess their need for children and their ability to raise them.
- Increasing female literacy and employment lowers the uncritical acceptance of childbearing and motherhood as measures of the status of women. Working women have less time to raise children; this is particularly an issue where fathers traditionally make little or no contribution to child-raising, such as southern Europe or Japan. Valuation of women beyond childbearing and motherhood becomes important.
- Improvements in contraceptive technology are now a major factor. Fertility decline is caused as much by changes in values about children and sex as by the availability of contraceptives and knowledge of how to use them.

The resulting changes in the age structure of the population include a reduction in the youth dependency ratio and eventuallypopulation aging. The population structure becomes less triangular and more like an elongated balloon. During the period between the decline in youth dependency and rise in old age dependency there is a demographic window of opportunity that can potentially produce economic growth through an increase in the ratio of working age to dependent population; the demographic dividend.

However, unless factors such as those listed above are allowed to work, a society's birth rates may not drop to a low level in due time, which means that the society cannot proceed to Stage Four and is locked in what is called a demographic trap. Countries that have experienced a fertility decline of over 40% from their pre-transition levels include: Costa Rica, El Salvador,Panama, Jamaica, Mexico, Colombia, Ecuador, Guyana, Philippines, Indonesia, Malaysia, Sri Lanka, Turkey, Azerbaijan,Turkmenistan, Uzbekistan, Egypt, Tunisia, Algeria, Morocco, Lebanon, South Africa, India, Saudi Arabia, and many Pacific islands.

Countries that have experienced a fertility decline of 25-40% include: Honduras, Guatemala, Nicaragua, Paraguay, Bolivia, Vietnam,Myanmar, Bangladesh, Tajikistan, Jordan, Qatar, Albania, United Arab Emirates, Zimbabwe, and Botswana.

Countries that have experienced a fertility decline of 10-25% include: Haiti, Papua New Guinea, Nepal, Pakistan, Syria, Iraq, Libya, Sudan, Kenya, Ghana and Senegal.

Stage Four

This occurs where birth and death rates are both low. Therefore the total population is high and stable. There is a low death rate because there are not a lot of diseases and famines and there is enough to eat. The birth rate is low because the people have more opportunities to choose if they want children; this is made possible by improvements in contraception or women gaining more rights enabling to be more independent and work focused (as opposed to just bearing children). Some theorists consider there are only 4 stages and that the population of a country will remain at this level. The DTM is only a suggestion about the future population levels of a country. It is not a prediction.

Countries that are at this stage (Total Fertility Rate of less than 2.5 in 1997) include: United States, Canada, Argentina, Australia, New Zealand, most of Europe, Bahamas, Puerto Rico, Trinidad and Tobago, Brazil, Sri Lanka, South Korea, Singapore, Iran, China, Turkey, Thailand and Mauritius.

Stage Five and/or Six

The original Demographic Transition model has just four stages, but additional stages have been proposed. Both more-fertile and less-fertile futures have been claimed as a Stage Five.

Some countries have sub-replacement fertility (that is, below 2.1 children per woman). This should be 2.1 because it replaces the two parents, and adds population for deaths with the added. child. European and many East Asian countries now have higher death rates than birth rates. Population aging and population decline may eventually occur, presuming that sustained mass immigration does not occur. In an article in the August 2009 issue of *Nature*, Myrskyla, Kohler and Billari show that the previously negative relationship between national wealth (as measured by the Human Development Index (HDI)) and birth rates has become J-shaped. Development promotes fertility decline at low and medium HDI levels, but advanced HDI promotes a rebound in fertility. In many countries with very high levels of development fertility rates are now approaching two children per woman — although there are exceptions, notably Germany and Japan. In the current century, the past decade as of 2012, most advanced countries have increased fertility. From the point of view of evolutionary biology, richer people having fewer children is odd, as natural selection usually favours individuals who are willing and able to convert plentiful resources into plentiful fertile descendants.

POPULATION COMPOSITION

Population composition is the description of a population according to characteristics such as age and sex. These data are often compared over time using population pyramids.

Importance of Indicator

The composition of the population is part of the social environment. It provides a framework against which to interpret the health status and behaviours of the population.

Background

Among OECD countries, Canada's population has a relatively small percentage of seniors.

In Japan 23% of the population is aged 65 or older, 20% in Italy and Germany. By contrast, India, Indonesia, and South Africa are at the other extreme, with 5% to 6% of their population in their senior years.

While the overall population is aging, within Canada, the Aboriginal population is relatively young. In 2006, fewer than 5% of the Aboriginal population were aged 65 or older. The median ages of the Aboriginal and non-Aboriginal populations were 27 and 40, respectively.

Highlights and Graphs

Age group and sex:

- In 2006 354,617 babies were born in Canada; for every 100 girls, 106 boys were born. This was up slightly from 2000 when 327,882 babies were born with the same male to female ratio as in 2006.
- In 2006 males comprised just over half of the population until around age 50 when females, having longer life expectancy, began to outnumber males; among seniors aged 85 or older, there were 2.2 females for every male.

Time trend:

- Young people under the age of 20 account for an ever decreasing proportion of the population; from 39% in 1971 to 24% in 2006. The size of the youth population is projected to decline to 18% by 2056.
- The working-age population increased as the baby boomers entered the workforce, but will decrease again when they start to leave this population in 2011.
- Seniors currently account for 14% of the population; by 2056, it is projected that their share of the population will rise to more than 27%.

POPULATION DYNAMICS AND PROCESS

Structure and Dynamics

Population of India. Although India occupies only 2. 4% of the world's land area, it supports over 15% of the world's population. Only China has a larger population. Almost 40% of Indians are younger than 15 years of age. About 70% of the people live in more than 550, 000 villages, and the remainder in more than 200 towns and cities. Over thousands of years of its history, India has been invaded from the Iranian plateau, Central Asia, Arabia, Afghanistan, and the West; Indian people and culture have absorbed and changed these influences to produce a remarkable racial and cultural synthesis. Religion, caste, and language are major determinants of social and political organization in India today. The government has recognized 18 languages as official; Hindi is the most widely spoken.

Although 83% of the people are Hindu, India also is the home of more than 120 million Muslims—one of the world's largest Muslim populations. The population also includes Christians, Sikhs, Jains, Buddhists, and Parsis. The caste system reflects Indian occupational and religiously defined hierarchies. Traditionally, there are four broad categories of castes (varnas), including a category of outcastes, earlier called "untouchables" but now commonly referred to as "dalits."

Within these broad categories there are thousands of castes and subcastes, whose relative status varies from region to region.

Despite economic modernization and laws countering discrimination against the lower end of the class structure, the caste system remains an important source of social identification for most Hindus and a potent factor in the political life of the country.

India Population: The 1991 final census count gave India a total population of 846, 302, 688. However, estimates of India's population vary widely. According to the Population Division of the United Nations Department of International Economic and Social Affairs, the population had already reached 866 million in

1991. The Population Division of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) projected 896. 5 million by mid-1993 with a 1. 9 percent annual growth rate. The United States Bureau of the Census, assuming an annual population growth rate of 1. 8 percent, put India's population in July 1995 at 936, 545, 814. These higher projections merit attention in light of the fact that the Planning Commission had estimated a figure of 844 million for 1991 while preparing the Eighth Five-Year Plan. India accounts for some 2. 4 percent of the world's landmass but is home to about 16 percent of the global population. The magnitude of the annual increase in population can be seen in the fact that India adds almost the total population of Australia or Sri Lanka every year. A 1992 study of India's population notes that India has more people than all of Africa and also more than North America and South America together. Between 1947 and 1991, India's population more than doubled.

Throughout the twentieth century, India has been in the midst of a demographic transition. At the beginning of the century, endemic disease, periodic epidemics, and famines kept the death rate high enough to balance out the high birth rate. Between 1911 and 1920, the birth and death rates were virtually equal—about forty-eight births and forty-eight deaths per 1, 000 population. The increasing impact of curative and preventive medicine (especially mass inoculations) brought a steady decline in the death rate. By the mid-1990s, the estimated birth rate had fallen to twenty-eight per 1, 000, and the estimated death rate had fallen to ten per 1, 000. Clearly, the future configuration of India's population (indeed the future of India itself) depends on what happens to the birth rate. Even the most optimistic projections do not suggest that the birth rate could drop below twenty per 1, 000 before the year 2000. India's population is likely to exceed the 1 billion mark before the 2001 census.

The upward population in India spiral began in the 1920s and is reflected in intercensal growth increments. South Asia's population increased roughly 5 percent between 1901 and 1911 and actually declined slightly in the next decade. Population increased some 10 percent in the period from 1921 to 1931 and 13 to 14 percent in the 1930s and 1940s. Between 1951 and 1961, the population rose 21. 5 percent. Between 1961 and 1971, the country's population increased by 24. 8 percent. Thereafter a slight slowing of the increase was experienced: from 1971 to 1981, the population increased by 24. 7 percent, and from 1981 to 1991, by 23. 9 percent.

Population in India density has risen concomitantly with the massive increases in population. In 1901 India counted some seventy-seven persons per square kilometer; in 1981 there were 216 persons per square kilometer; by 1991 there were 267 persons per square kilometer—up almost 25 percent from the 1981 population density. India's average population density is higher than that of any other nation of comparable size. The highest densities are not only in heavily urbanized regions but also in areas that are mostly agricultural. Population of India growth in the years between 1950 and 1970 centred on areas of new irrigation projects, areas subject to refugee resettlement, and regions of urban expansion. Areas where population did not increase at a rate approaching the national average were those facing the most severe economic hardships, overpopulated rural areas, and regions with low levels of urbanization.

The 1991 census, which was carried out under the direction of the Registrar General and Census Commissioner of India (part of the Ministry of Home Affairs), in keeping with the previous two censuses, used the term *urban agglomerations*. An urban agglomeration forms a continuous urban spread and consists of a city or town and its urban outgrowth outside the statutory limits. Or, an urban agglomerate may be two or more adjoining cities or towns and their outgrowths. A university campus or military base located on the outskirts of a city or town, which often increases the actual urban area of that city or town, is an example of an urban agglomeration. In India urban agglomerations with a population of 1 million or more—there were twenty-four in 1991—are referred to as metropolitan areas. Places with a population of 100, 000 or more are termed "cities" as compared with "towns, " which have a population of less than 100, 000. Including the metropolitan areas, there were 299 urban agglomerations with more than 100, 000 population in 1991. These large urban agglomerations are designated as Class I urban units. There were five other classes of urban agglomerations, towns, and villages based on the size of their populations: Class II (50, 000 to 99, 999), Class III (20, 000 to 49, 999), Class IV (10, 000 to 19, 999), Class V (5, 000 to 9, 999), and Class VI (villages of less than 5, 000.

The results of the 1991 census revealed that around 221 million, or 26. 1 percent, of Indian's population lived in urban areas. Of this total, about 138 million people, or 16 percent, lived in the 299 urban agglomerations. In 1991 the twenty-four metropolitan cities accounted for 51 percent of India's total population living in Class I urban centres, with Bombay and Calcutta the largest at 12. 6 million and 10. 9 million, respectively.

In the early 1990s, growth was the most dramatic in the cities of central and southern India. About twenty cities in those two regions experienced a growth rate of more than 100 percent between 1981 and 1991. Areas subject to an influx of refugees also experienced noticeable demographic changes. Refugees from Bangladesh, Burma, and Sri Lanka contributed substantially to population growth in the regions in which they settled. Less dramatic population increases occurred in areas where Tibetan refugee settlements were founded after the Chinese annexation of Tibet in the 1950s.

The majority of districts had urban populations ranging on average from 15 to 40 percent in 1991. According to the 1991 census, urban clusters predominated in the upper part of the Indo-Gangetic Plain; in the Punjab and Haryana plains, and in part of western Uttar Pradesh. The lower part of the Indo-Gangetic Plain in southeastern Bihar, southern West Bengal, and northern Orissa also experienced increased urbanization. Similar increases occurred in the western coastal state of Gujarat and the union territory of Daman and Diu. In the Central Highlands in Madhya Pradesh and Maharashtra, urbanization was most noticeable in the river basins and adjacent plateau regions of the Mahanadi, Narmada, and Tapti rivers. The coastal plains and river deltas of the east and west coasts also showed increased levels of urbanization.

The hilly, inaccessible regions of the Peninsular Plateau, the northeast, and the Himalayas remain sparsely settled. As a general rule, the lower the population density and the more remote the region, the more likely it is to count a substantial portion of tribal people among its population. Urbanization in some sparsely settled regions is more developed than would seem warranted at first glance at their limited natural resources. Areas of western India that were formerly princely states (in Gujarat and the desert regions of Rajasthan) have substantial urban centres that originated as political-administrative centres and since independence have continued to exercise hegemony over their hinterlands.

The vast majority of Indians, nearly 625 million, or 73. 9 percent, in 1991 lived in what are called villages of less than 5, 000 people or in scattered hamlets and other rural settlements. The states with proportionately the greatest rural populations in 1991 were the states of Assam (88. 9 percent), Sikkim (90. 9 percent) and Himachal Pradesh (91. 3 percent), and the tiny union territory of Dadra and Nagar Haveli (91. 5 percent). Those with the smallest rural populations proportionately were the states of Gujarat (65. 5 percent), Maharashtra (61. 3 percent), Goa (58. 9 percent), and Mizoram (53. 9 percent). Most of the other states and the union territory of the Andaman and Nicobar Islands were near the national average. Two other categories of India's population that are closely scrutinized by the national census are the Scheduled Castes and Scheduled Tribes. The greatest concentrations of Scheduled Caste members in 1991 lived in the states of Andhra Pradesh (10. 5 million, or nearly 16 percent of the state's population), Tamil Nadu (10. 7 million, or 19 percent), Bihar (12. 5 million, or 14 percent), West Bengal (16 million, or 24 percent), and Uttar Pradesh (29. 3 million, or 21 percent). Together, these and other Scheduled Caste members comprised about 139 million people, or more than 16 percent of the total population of India. Scheduled Tribe members represented only 8 percent of the total population (about 68 million). They were found in 1991 in the greatest numbers in Orissa (7 million, or 23 percent of the state's population), Maharashtra (7. 3 million, or 9 percent), and Madhya Pradesh (15. 3 million, or 23 percent). In proportion, however, the populations of states in the northeast had the greatest concentrations of Scheduled Tribe members.

ENVIRONMENTAL IMPLICATIONS OF SPECIFIC POPULATION FACTORS

According to recent United Nations estimates, global population is increasing by approximately 80 million — the size of Germany — each year. Although fertility rates have declined in most areas of the world, population growth continues to be fueled by high levels of fertility, particularly in Asia and Africa. In numerous Middle Eastern and African nations, the average number of children a woman would be expected to have given current fertility levels remains above 6.0 — for example, 6.4 in Saudi Arabia, 6.7 in Yemen, 6.9 in Uganda, and as high as 7.5 in Niger. Even in areas where fertility rates have declined to near replacement levels (2.1 children per couple), population continues to grow because of "population momentum," which occurs when a high proportion of the population is young.

Population Size

No simple relationship exists between population size and environmental change. However, as global population continues to grow, limits on such global resources as arable land, potable water, forests, and fisheries have come into sharper focus. In the second half of the twentieth century, decreasing farmland contributed to growing concern of the limits to global food production. Assuming constant rates of production, per capita land requirements for food production will near the limits of arable land over the course of the twenty-first century. Likewise, continued population growth occurs in the context of an accelerating demand for water: Global water consumption rose sixfold between 1900 and 1995, more than double the rate of population growth.

Population Distribution

The ways in which populations are distributed across the globe also affect the environment. Continued high fertility in many developing regions, coupled with low fertility in more-developed regions, means that 80 percent of the global population now lives in less-developed nations. Furthermore, human migration is at an all-time high: the net flow of international migrants is approximately 2 million to 4 million per year and, in 1996, 125 million people lived outside their country of birth. Much of this migration follows a rural-to-urban pattern, and, as a result, the Earth's population is also increasingly urbanized. As recently as 1960, only one-third of the world's population lived in cities. By 1999, the percentage had increased to nearly half (47 percent). This trend is expected to continue well into the twenty-first century.

The distribution of people around the globe has three main implications for the environment. First, as less-developed regions cope with a growing share of population, pressures intensify on already dwindling resources within these areas. Second, migration shifts relative pressures exerted on local environments, easing the strain in some areas and increasing it in others. Finally, urbanization, particularly in less-developed regions, frequently outpaces the development of infrastructure and environmental regulations, often resulting in high levels of pollution.

Population Composition

Composition can also have an effect on the environment because different population subgroups behave differently. For example, the global population has both the largest cohort of young people (age 24 and under) and the largest proportion of elderly in history. Migration propensities vary by age. Young people are more likely than their older counterparts to migrate, primarily as they leave the parental home in search of new opportunities. As a result, given the relatively large younger generation, we might anticipate increasing levels of migration and urbanization, and therefore, intensified urban environmental concerns.

Other aspects of population composition are also important: Income is especially relevant to environmental conditions. Across countries, the relationship between economic development and environmental pressure resembles an inverted U-shaped curve; nations with economies in the middle-development range are most likely to exert powerful pressures on the natural environment, mostly in the form of intensified resource consumption and the production of wastes. By contrast, the least-developed nations, because of low levels of industrial activity, are likely to exert relatively lower levels of environmental pressure. At highly advanced development stages, environmental pressures may subside because of improved technologies and energy efficiency.

Within countries and across households, however, the relationship between income and environmental pressure is different. Environmental pressures can be greatest at the lowest and highest income levels. Poverty can contribute to unsustainable levels of resource use as a means of meeting short-term subsistence needs. Furthermore, higher levels of income tend to correlate with disproportionate consumption of energy and production of waste.

MEDIATING FACTORS: TECHNOLOGY, POLICY CONTEXTS, AND CULTURAL FACTORS

Current technology, policies, and culture influence the relationship between human population dynamics and the natural environment. The technological changes that have most affected environmental conditions relate to energy use. The consumption of oil, natural gas, and coal increased dramatically during the twentieth century. Until about 1960, developed nations were responsible for most of this consumption. Since then, however, industrialization in the newly developing nations has resulted in greater reliance on resource- intensive and highly polluting production processes.

Policy actions can ameliorate environmental decline — as in the case of emissions standards — or exacerbate degradation as in the case in Central Asia's Aral Sea basin, which has shrunk 40 percent since 1960 and has become increasingly contaminated, in large part because of the irrigation policies of the former Soviet Union. Cultural factors also influence how populations affect the environment. For example, cultural variations in attitudes toward wildlife and conservation influence environmental conservation strategies, because public support for various policy interventions will reflect societal values.

Two Specific Areas of Population-Environment Interaction

Two specific areas illustrate the challenges of understanding the complex influence of population dynamics on the environment: land-use patterns and global climate change.

Land Use

Fulfilling the resource requirements of a growing population ultimately requires some form of land-use change—to provide for the expansion of food production through forest clearing, to intensify production on already cultivated land, or to develop the infrastructure necessary to support increasing human numbers. During the past three centuries, the amount of Earth's cultivated land has grown by more than 450 percent, increasing from 2.65 million square kilometers to 15 million square kilometers. A related process, deforestation, is also critically apparent: A net decline in forest cover of 180 million acres took place during the 15-year interval 1980–1995, although changes in forest cover vary greatly across regions. Whereas developing countries experienced a net loss of 200 million acres, developed countries actually experienced a net increase, of 20 million acres.

These types of land-use changes have several ecological impacts. Converting land to agricultural use can lead to soil erosion, and the chemicals often used in fertilizers can also degrade soil. Deforestation is also associated with soil erosion and can lessen the ability of soil to hold water, thereby increasing the frequency and severity of floods. Human-induced changes in land use often result in habitat fragmentation and loss, the primary cause of species decline. In fact, if current rates of forest clearing continue, one-quarter of all species on Earth could be lost within the next 50 years.

Global Climate Change

Recent years have been among the warmest on record. Research suggests that temperatures have been influenced by growing concentrations of greenhouse gases, which absorb solar radiation and warm the atmosphere. Research also suggests that many changes in atmospheric gas are human-induced. The demographic influence appears primarily in three areas. First, contributions related to industrial production and energy consumption lead to carbon dioxide emissions from fossil fuel use; second, land-use changes, such as deforestation, affect the exchange of carbon dioxide between the Earth and the atmosphere; and third, some agricultural processes, such as paddy-rice cultivation and livestock production, are responsible for greenhouse gas releases into the atmosphere, especially methane. According to one estimate, population growth will account for 35 percent of the global increase in CO_2 emissions between 1985 and 2100 and 48 percent of the increase in developing nations during that period. As such, both attention to demographic issues and the development of sustainable production and consumption processes are central responses to the processes involved in global warming.

What Should Policymakers Do?

The policy implications of demographic influences on the environment are complicated and can sometimes be controversial. While some view large, rapidly growing populations in developing regions as the primary culprit in environmental decline, others focus on the costly environmental effects of overconsumption among the slowly increasing populations of the developed nations. These differing emphases naturally point to radically different solutions: slow population increase in less-developed nations or change destructive consumption and production patterns in the more-developed nations. This debate, however, presumes a one-step solution to the complex problems created by population pressures on the environment. Both population size and consumption influence environmental change and are among the many factors that need to be incorporated into realistic policy debate and prescriptions. Examples of policies that could address the environmental implications of demographic factors include policies to promote effective family planning, more effective rural development to slow migration to crowded urban centers, and incentives to encourage sustainable levels of consumption and the use of efficient, cleaner technologies.

POPULATION, DEVELOPMENT AND THE ENVIRONMENT

Billions of ordinary people share the same aspirations: a secure life, a place to live, economic opportunity for themselves, education and health care for their children. Modest goals—yet half the world go their whole lives without even coming close.

The great challenge of the 21st century is to enable everyone to live a life of dignity. It can be done – the world has never seen such wealth. It must be done, because over-consumption, waste and poverty are combining to destroy the environment that supports us all. Global warming is a fact, with rising sea levels and unpredictable climate change. Rapid population growth is a fact, with the poorest countries and the poorest areas asked to bear the biggest increases. Species destruction is a fact, with more and more people depending on a shrinking base of natural resources. Stress on food and water resources are facts, with the severest stresses in the most needy areas.

We have limited time to correct these imbalances that imperil our world. Whoever we are, wherever we live, each one of us has a responsibility.

The most important steps are the most basic. Human security and well-being start with education and health care for all. These are human rights, but they also empower women and men. They are the basic equipment to exercise responsibility in the modern world.

The goals of universal education and health care are agreed. They are within reach. Meeting them would cost a fraction of today's expenditure on less important things – arms for example.

Universal education and health care would also have multiple benefits, especially for women, who lag behind in both areas.

Reproductive rights are part of the right to health. Better reproductive health is important for men, but it is vital for women: one woman every minute dies of causes related to pregnancy, and four women every minute catch the infection that leads to AIDS. Better reproductive health means fewer unwanted pregnancies and fewer HIV infections. The AIDS pandemic will end when there are no more new infections.

Reproductive health is integrally linked to sustainable development. Women who can choose have smaller families; and that means slower population growth—a little more time to meet basic needs and make vital decisions.

All this was agreed nearly seven years ago, at the International Conference on Population and Development 1994. It was reaffirmed two years ago at the ICPD five-year review. This World Population Day, we must renew our commitment to ICPD goals. We must accept our responsibilities to ourselves and to each other. We must find the balance that will renew our world and enable all of its people to meet their aspirations.

LIFE AND THE ENVIRONMENT

Life is adapted to nearly all Earth surface environments:

- Places to live
- Climatic constraints on living
- Other physical constraints on living
- Ways of living

Individuals, species, and populations, both marine and terrestrial, tend to live in particular places. These places are called habitats. Each habitat is characterized by a specific set of environmental conditions—radiation and light, temperature, moisture, wind, fire frequency and intensity, gravity, salinity, currents, topography, soil, substrate, geomorphology, human disturbance, and so forth.

A place to live: habitats

Habitats come in all shapes and sizes, occupying the full sweep of geographical scales. They range from small (microhabitats), through medium (mesohabitats) and large (macrohabitats), to very large (megahabitats). Microhabitats are a few square centimetres to a few square metres in area. They include leaves, the soil, lake bottoms, sandy beaches, talus slopes, walls, river banks, and paths. Mesohabitats have areas up to about 10,000 km^2; that is, a 100×100 kilometre square, which is about the size of Cheshire, England. Each main mesohabitat is influenced by the same regional climate, by similar features of geomorphology and soils, and by a similar set of disturbance regimes. Deciduous woodland, caves, and streams are examples. Macrohabitats have areas up to about 1,000,000 km^2, which is about the size of Ireland. Megahabitats are regions more than 1,000,000 km^2 in extent. They include continents and the entire land surface of the Earth. Landscape ecologists, who have an express interest in the geographical dimension of ecosystems, recognize three levels of 'habitat'—region, landscape, and landscape element. These correspond to large-scale, medium-scale, and small-scale habitats. Some landscape ecologists are relaxing their interpretation of a landscape to include smaller and larger scales—they have come to realize that a beetle's view or a bird's view of the landscape is very different from a human's view.

Landscapes

Landscape elements combine to form landscapes. A landscape is a mosaic, an assortment of patches and corridors set in a matrix, no bigger than about 10,000 km^2. It is 'a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout'. By way of example, the recurring cluster of interacting ecosystems that feature in the landscape around the author's home, in the foothills of the Pennines, includes woodland, field, hedgerow, pond, brook, canal, roadside, path, quarry, mine tip, disused mining incline, disused railway, farm building, and residential plot.

Regions

Landscapes combine to form regions, more than about 10,000 km^2 in area. They are collections of landscapes sharing the same macroclimate. All Mediterranean landscapes share a seasonal climate characterized by mild, wet winters and hot, droughty summers.

Habitat requirements

It is probably true to say that no two species have exactly the same living requirements. There are two extreme cases—fussy species or habitat specialists and unfussy species or habitat generalists—and all grades of 'fussiness' between.

Habitat Specialists

Habitat specialists have very precise living requirements. In southern England, the red ant, *Myrmica sabuleti,* needs dry heathland with a warm south-facing aspect that contains more than 50 per cent grass species, and that has been disturbed within the previous five years. Other species are less pernickety and thrive over a wider range of environmental conditions. The three-toed woodpecker *(Picoides tridactylus)* lives in a broad swath of cool temperate forest encircling the Northern Hemisphere. Races of the common jay *(Garrulus glandarius)* occupy a belt of oak and mixed deciduous woodland stretching from Britain to Japan.

Habitat Generalists

A few species manage to eke out a living in a great array of environments. The human species *(Homo sapiens)* is the champion habitat generalist —the planet Earth is the human habitat. In the plant kingdom, the broad-leaved plantain *(Plantago major),* typically a species of grassland habitats, is found almost everywhere except Antarctica and the dry parts of North Africa and the Middle East. In the British Isles, it seems indifferent to climate and soil conditions, being found in all grasslands on acid and alkaline soils alike. It also lives on paths, tracks, disturbed habitats (spoil heaps, demolition sites, arable land), pasture and meadows, road verges, river banks, mires, skeletal habitats, and as a weed in lawns and sports fields. In woodland, it is found only in relatively unshaded areas along rides. It is not found in aquatic habitats or tall herb communities.

Life's Limits: Ecological Tolerance

Organisms live in virtually all environments, from the hottest to the coldest, the wettest to the driest, the most acidic to the most alkaline. Understandably, humans tend to think of their 'comfortable' environment as the norm. But moderate conditions are anathema to the micro-organisms that love conditions fatal to other creatures. These are the extremophiles. An example is high-pressure-loving microbes (barophiles) that flourish in deep-sea environments and are adapted to life at high pressures. Many other organisms are adapted to conditions that, by white western human standards, are harsh, though not so extreme as the conditions favoured by the extremophiles. Examples are hot deserts and Arctic and alpine regions.

Limiting Factors

A limiting factor is an environmental factor that slows down population growth. The term was first suggested by Justus von Liebig, a German agricultural chemist. Liebig noticed that the growth of a field crop is limited by whichever nutrient happens to be in short supply. A field of wheat may have ample phosphorus to yield well, but if another nutrient, say nitrogen, should be lacking, then the yield will be reduced. No matter how much extra phosphorus is applied in fertilizer, the lack of nitrogen will limit wheat yield. Only by making good the nitrogen shortage could yields be improved. These observations led to Liebig to establish a 'law of the minimum': the productivity, growth, and reproduction of organisms will be constrained if one or more environmental factors lies below its limiting level.

Later, ecologists established a 'law of the maximum'. This law applies where population growth is curtailed by an environmental factor exceeding an upper limiting level. In a wheat field, too much phosphorus is as harmful as too little—there is an upper limit to nutrient levels that plants can tolerate.

Tolerance Range

For every environmental factor (such as temperature and moisture) there is a lower limit below which a species cannot live, an optimum range in which it thrives, and an upper limit above which it cannot live. The upper and lower bounds define the tolerance range of a species for a particular environmental factor. The bounds vary from species to species. A species will prosper within its optimum range of tolerance; survive but show signs of physiological stress near its tolerance limits; and not survive outside its tolerance range. Stress is a widely used but troublesome idea in ecology. It may be defined as 'external constraints limiting the rates of resource acquisition, growth or reproduction of organisms'.

Each species (or race) has a characteristic tolerance range. Stenoecious species have a wide tolerance; euryoecious species have a narrow tolerance. All species, regardless of their tolerance range, may be adapted to the low end, to the middle, or to the high end (polytypic) of an environmental gradient. Take the example of photosynthesis in plants. Plants adapted to cool temperatures (oligotherms) have photosynthetic optima at about 10°C and cease to photosynthesize above 25°C. Temperate-zone plants (mesotherms) have optima between 15°C and 30°C. Tropical plants (polytherms) may have optima as high as 40°C. Interestingly, these optima are not 'hard and fast'. Cold-adapted plants are able to shift their photosynthetic optima towards higher temperatures when they are grown under warmer conditions.

Ecological Valency

Tolerance may be wide or narrow and the optimum may be at low, middle, or high positions along an environmental gradient. When combined, these contingencies produce six grades of ecological valency. The glacial flea *(Isotoma saltans)* has a narrow temperature tolerance and likes it cold.

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