# TWO-YEAR
# POST GRADUATE DEGREE PROGRAMME (CBCS)
# IN
# BOTANY

**SEMESTER - III**

## Course: BOTCOR T311

## (Plant Ecology, Biodiversity & Conservation)

**Self-Learning Material**

**DIRECTORATE OF OPEN AND DISTANCE LEARNING**
**UNIVERSITY OF KALYANI**
**KALYANI – 741235, WEST BENGAL**

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**July 2023**
Directorate of Open and Distance Learning, University of Kalyani

Published by the Directorate of Open and Distance Learning, University of Kalyani, Kalyani741235, West Bengal

# <u>Director's Messeage</u>

Satisfying the varied needs of distance learners, overcoming the obstacle of distance and reaching the unreached students are the threefold functions catered by Open and Distane Learning (ODL) systems. The onus lies on writers, editors, production professionals and other personal involved in the process to overcome the challenges inherent to curriculam design and production of relevant Self Learning Materials (SLMs). At the University of Kalyani a dedicated team under the able guidance of the Hon'ble Vice-Chancellor has invested its best efforts, professionally and in keeping with the demands of Post Graduate CBCS Programmes in Distance Mode to devise a self-sufficient curriculum for each course offered by the Directorate of Open and Distane Learning (DODL) University of Kalyani.

Development of printed SLMs for students admitted to the DODL within a limited time to cater to the academic requirements of the Course as per standards set by Distance Education Bureau of the University Grants Commission, New Delhi, India under Open and Distance Mode UGC-DEB Regulations, 2020 had been our endeavour. We are happy to have achieved our goal.

Utmost care and precision have been ensured in the development of SLMs, making them useful to the lesrners, besides avoiding errors as far as practicable. Further, suggestions from the stakeholders in this would be welcome.

During the production-process of the SLMs, the team continuously received positive stimulations and feedback from Professor (Dr.) Amalendu Bhunia, Hon'ble Vice-Chancellor, University of Kalyani, who kindly accorded directions, encouragements and suggestions, offered constructive criticisms to develop it within proper requirements. We gracefully, acknowledge his inspiration and guidance.

Sincere gratitude is due to the respective chairpersons as well as each and every Members of PGBOS (DODL), University of Kalyani, Heartfelt thanks is also due to the Course Writers- faculty members at the DODL, subject-experts serving at University Post Graduate departments and also to the authors and academicians whose academic contributions have enriched the SLMs. We humbly acknowledge their valuable academic contributions. I would especially like to convey gratitude to all other University dignitaries and personnel involved either at the conceptual or operational level of the DODL of University of Kalyani.

Their persistent and co-ordinated efforts have resulted in the compilation of comprehensive, learners friendly, flexible text that meets curriculum requirements of the Post Graduate Programme through distance mode.



All the Self Learning Materials are self-writing and collected from e-Book, journals and websites.

Director
Directorate of Open & Distance Learning
University of Kalyani

**SYLLABUS**

**COURSE – BOTCOR T311**

**Plant Ecology, Biodiversity & Conservation**

**(Full Marks – 75)**

| Course | Group | Details Contents Structure | | Study hour |
|---|---|---|---|---|
| BOTCOR T311 | Plant Ecology | **Unit 1. Introduction to Ecology** | 1. Introduction to Ecology: Scope and nature of plant ecology. | 1 |
| | | **Unit 2. Approaches in Ecological Studies** | 2. Approaches in Ecological Studies: formulating hypothesis; theoretical ecological models; probabilistic ecological models. | 1 |
| | | **Unit 3. Introduction to Climatology** | 3. Introduction to Climatology: Atmospheric variables, Remote Sensing, Climate Diagrams. | 1 |
| | | **Unit 4. Abiotic and Biotic Environment – I** | 4. Abiotic and Biotic Environment: variables in action; influence of abiotic environment on distribution and abundance of plants. | 1 |
| | | **Unit 5. Abiotic and Biotic Environment – II** | 5. Abiotic and Biotic Environment: influence of biotic environment on distribution and abundance of plants; levels of organization of organisms in ecology. | 1 |
| | | **Unit 6. Habitat and Niche** | 6. Habitat and Niche: concept of habitat and niche; niche width and overlap; fundamental and realized niche; competitive exclusion principle; extinction; resource partitioning; character displacement; speciation. | 1 |
| | | **Unit 7. Population Ecology – I** | 7. Population Ecology: characteristics of population; population growth curves, population regulation, life history strategies (r and K selection). | 1 |

| Course | Group | Details Contents Structure | | Study hour |
|---|---|---|---|---|
| BOTCOR T311 | Plant Ecology | **Unit 8. Population Ecology – II** | 8. Population Ecology: Metapopulation, habitat fragmentation, demes, source-sink model; population interactions (competition, parasitism, mutualism). | 1 |
| | | **Unit 9: Community Ecology – I** | 9. Community Ecology: concepts of community, assemblage and guilds; open and closed communities, ecotone; community continuum concept; community structure. | 1 |
| | | **Unit 10. Community Ecology – II** | 10. Community Ecology: Measures of community structure – diversity indices, similarity measures, food web analysis; succession - types, mechanisms, concept of climax. | 1 |
| | | **Unit 11. Ecosystem Ecology – I** | 11. Ecosystem Ecology: concept of ecosystem. | 1 |
| | | **Unit 12. Ecosystem Ecology – II** | 12. Ecosystem Ecology: Disturbance (natural and anthropogenic) and their impact on plant ecology; invasive plant species; resistance and resilience of ecosystems. | 1 |
| | | **Unit 13. Biogeography** | 13. Biogeography: biogeographic patterns; biomes; major biogeographical regions of India. | 1 |
| | | **Unit 14. Environmental Economics** | 14. Environmental Economics: Introduction; valuation; sustainable development. | 1 |

| Course | Group | Details Contents Structure | | Study hour |
|---|---|---|---|---|
| BOTCOR T311 | Biodiversity & Conservation | **Unit 15. Biodiversity** | 1. Biodiversity: Concept, kinds/ levels, importance, methods of study, protection from depletion; Mega - diversity and Hotspots. | 1 |
| | | **Unit 16. Threats to Biodiversity** | 2. Threats to Biodiversity: Causes of threats; Concepts of rare, vulnerable, endangered and threatened plants (IUCN categories). | 1 |
| | | **Unit 17. Conservation** | 3. Conservation: Types of conservation - in-situ conservation: Biosphere Reserve, Wildlife Sanctuaries, National Parks, World Heritage Sites; Concept and types of Protected Areas Networks; ex-situ conservation: principles, methods, definition, aims and activities of W.W.F., Red Data Book, MAB, CITES, Role of Botanic Gardens and Gene Banks. | 1 |
| | | **Unit 18. Legal aspects of biodiversity and conservation** | 4. Legal aspects of biodiversity and conservation: International Conventions; Important National legal instruments – Acts, Rules and Policies. | 1 |

# Content

# COURSE – BOTCOR T310

## Plant Molecular Biology and Biotechnology

**Hard Core Theory Paper** **Credits (A+B): = 3**

## Group – A (Plant Ecology)

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## Content Structure

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1. Introduction
2. Course Objective
3. Introduction to Ecology: Scope and nature of plant ecology.
4. Approaches in Ecological Studies: formulating hypothesis; theoretical ecological models; probabilistic ecological models.
5. Introduction to Climatology: Atmospheric variables, Remote Sensing, Climate Diagrams.
6. Abiotic and Biotic Environment: variables in action; influence of abiotic environment on distribution and abundance of plants; levels of organization of organisms in ecology.
7. Habitat and Niche: concept of habitat and niche; niche width and overlap; fundamental and realized niche; competitive exclusion principle; extinction; resource partitioning; character displacement; speciation.
8. Population Ecology: characteristics of population; population growth curves, population regulation, life history strategies (r and K selection); metapopulation, habitat fragmentation, demes, source-sink model; population interactions (competition, parasitism, mutualism).
9. Community Ecology: concepts of community, assemblage and guilds; open and closed communities, ecotone; community continuum concept; community structure; measures of community structure – diversity indices, similarity measures, food web analysis; succession - types, mechanisms, concept of climax.

10. Ecosystem Ecology: concept of ecosystem, disturbance (natural and anthropogenic) and their impact on plant ecology; invasive plant species; resistance and resilience of ecosystems.
11. Biogeography: biogeographic patterns; biomes; major biogeographical regions of India.
12. Environmental Economics: Introduction; valuation; sustainable development.
13. Let's sum up
14. Suggested Readings
15. Assignments

## 1. Introduction

Ecology is the branch of biology which studies the interactions among organisms and their environment. Objects of study include interactions of organisms with each other and with abiotic components of their environment. Topics of interest include the biodiversity, distribution, biomass, and populations of organisms, as well as cooperation and competition within and between species The two groups have to coexist in order to share the resources that are available within the environmental ecosystem. To understand about this mutual co relationship we need to study and understand ecology. Organism ecology: This studies how different living organisms respond to stimuli caused by physical environment.

Conservation biologists are concerned with the protection and sustainability of natural resources like air, water, land and wildlife. In post degree level in a scientific field like biology this course is needed for teaching and research.

## 2. Course Objectives

After completion of the course the learners will be able to:

- To know about the nature of plant ecology
- Distinguish between abiotic and biotic environment.
- Describe different biogeographical region of India
- To understand population and community ecology
- Explain types of conservation and IUCN categories

## 3. Introduction to Ecology: Scope and nature of plant ecology.

**Introduction:**

The word "ecology" ("**oekologie**") (coined by German scientist **Ernst Haeckel,1866**) was derived from the Greek —**oikos**" meaning "**household**" and logos meaning "science:" the "**study of the household of nature**."

**Ecology:** branch of science that deals with interaction between living organisms with each other and their surroundings. Ecological systems are studied at several different levels from individuals and populations to ecosystems and biosphere level. Ecology is a multi-disciplinary science, drawing on many other branches of science. Applied ecology is the practice of employing ecological principles and understanding to solve real world problems. E.g. calculating fish population, measuring environmental impact from construction or logging, building a case for the conservation of a species, and determining the most effective way to protect a species.

Ecology is the study of the interactions of living organisms with their environment. Within the discipline of ecology, researchers work at four specific levels, sometimes discretely and sometimes with overlap. These levels are organism, population, community, and ecosystem. In ecology, ecosystems are composed of dynamically-interacting parts, which include organisms, the communities they comprise, and the non-living (abiotic) components of their environment. Ecosystem processes, such as primary production, pedogenesis (the formation of soil), nutrient cycling, and various niche construction activities, regulate the flux of energy and matter through an environment. These processes are sustained by organisms with specific life-history traits. The variety of organisms, called biodiversity, which refer to the differing species, genes, and ecosystems, enhances certain ecosystem services.

**Scope of Ecology:**

The solution of a particular ecological problem requires several lines of approach. None of this constitutes an end in itself but each one of these makes important contribution in making the picture com•plete.

These various lines of approach towards the ecological problem can be translated as:

1. **Biotic**
2. **Quantitative**
3. **Climatic (both physical and chemical)**
4. **Taxonomic**
5. **Genetic and evolutionary**

Biotic factors are the direct outcome of the various types of activities amongst the animals. A competition for food and shelter always exists amongst the members of a community. This competition demands various types of activity amongst the animals.

Quantitative study includes an assessment of the population density in a given area and also an estimation of the number of members present in different communities. Information of this kind is of immense value in solving many problems like food availability and movement within a particular colony.

Climatic factors include both physical and chemical conditions present in a habitat. These factors are ever changing in nature. Physical factors include mainly temperature, light and humidity. Chemical sensitive that a minute climatic change becomes fatal to them. Climatic factors play an important role in the distribution of animals.

Taxonomy means classification, naming and description of organisms. A mere naming of a large number of animals of a given area, as was done earlier in ecological surveys, is meaningless without a consideration of the circumstances that enable them to live there. Thus a complementary observation of the various ecological factors together with taxonomy is emphasized in ecology.

The genetic and evolutionary aspects have taken a rightful place in ecological problems.

In recent years the knowledge of heredity and the mechanism of the operation of Natural Selection have increased to a considerable extent.

Evolution is no longer regarded as a thing of the past and it has been proved that evolution is a dynamic process though the progress is very slow. In certain circumstances it has become possible to detect and to measure the rate of evolution in wild population.

The above subdivisions form the backbone of the study of ecology. The interrelationship existing between these subdivisions can be best understood with the help of an example. Let us assume that we want to study the ecology of a given species of edible fish inhabiting a large lake, with an object of establishing a new colony of these fishes to be started elsewhere.

In so doing, the first information that we need is that whether the food available in the new place is to be taken by these fishes. Our second enquiry would be to find out whether predators are present in the locality.

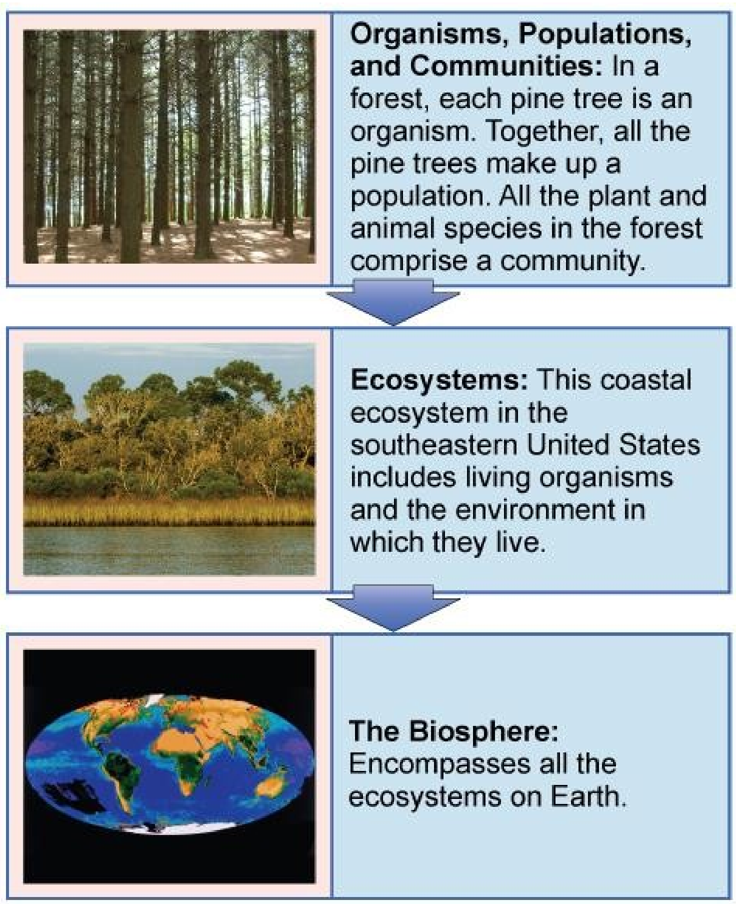
These two are included within the biotic factors. We will have to determine the number of fishes that are to be let loose in the new locality and the number is to be determined in such a way that they can live there without being overcrowded.

Herein lays the involvement of the quantitative aspect. We will have to study the water itself and to find out the extent of the fluctuations in its constitution such as salt content, acidity or alkalinity in order to determine the tolerance of the fishes in the changing factors.

If the first lake is a very old one and the fish in question had been isolated there for a great period of time, it is possible that a subspecies or local race might evolve there. In such cases the taxonomist might come forward and help identifying the species. Such a situation opens up a case for the Geneticists and Evolutionists to find out how and at what rate the new forms have evolved.

**Levels of Ecological Study:**

When a discipline such as biology is studied, it is often helpful to subdivide it into smaller, related areas. For instance, cell biologists interested in cell signaling need to understand the chemistry of the signal molecules (which are usually proteins) as well as the result of cell signaling. Ecologists interested in the factors that influence the survival of an endangered species might use mathematical models to predict how current conservation efforts affect endangered organisms. To produce a sound set of management options, a conservation biologist needs to collect accurate data, including current population size, factors affecting reproduction (like physiology and behavior), habitat requirements (such as plants and soils), and potential human influences on the endangered population and its habitat (which might be derived through studies in sociology and urban ecology). Within the discipline of ecology, researchers work at four specific levels, sometimes discretely and sometimes with overlap: organism, population, community, and ecosystem.



- **Organism:** Organismal ecologists study adaptations, beneficial features arising by natural selection that allow organisms to live in specific habitats. These adaptations can be morphological, physiological, or behavioral.
- **Population:** A population is a group of organisms of the same species that live in the same area at the same time. Population ecologists study the size, density, and structure of populations and how they change over time.
- **Community:** A biological community consists of all the populations of different species that live in a given area. Community ecologists focus on interactions between populations and how these interactions shape the community.
- **Ecosystem:** An ecosystem consists of all the biotic and abiotic factors that influence that community. Ecosystem ecologists often focus on flow of energy and recycling of nutrients.
- **Biosphere:** The biosphere is planet Earth, viewed as an ecological system. Ecologists working at the biosphere level may study global patterns—for example, climate or species distribution—interactions among ecosystems, and phenomena that affect the entire globe, such as climate change.

In essence, ecologists seek to explain:

- life processes
- interactions, interrelationships, behaviors, and adaptations of organisms
- the movement of materials and energy through living communities
- the successional development of ecosystems
- the abundance and distribution of organisms and biodiversity in the context of theenvironment

There are many practical applications of ecology in conservation biology, wetland management, natural resource management (agroecology, agriculture, forestry, agroforestry, fisheries), city planning (urban ecology), community health, economics, basic and applied science, and human social interaction (human ecology). Organisms and resources comprise ecosystems which, in turn, maintain biophysical feedback mechanisms that moderate processes acting on living (biotic) and nonliving (abiotic) components of the planet. Ecosystems sustain life-supporting functions and produce natural capital, such as biomass production (food, fuel, fiber and medicine), the regulation of climate, global biogeochemical cycles, water filtration, soil formation, erosion control, flood protection, and many other natural features of scientific, historical, economic, or intrinsic value.

There are also many subcategories of ecology, such as ecosystem ecology, animal ecology, and plant ecology, which look at the differences and similarities of various plants in various climates and

habitats. In addition, physiological ecology, or ecophysiology, studies the responses of the individual organism to the environment, while population ecology looks at the similarities and dissimilarities of populations and how they replace each other over time.

Finally, it is important to note that ecology is not synonymous with environment, environmentalism, natural history, or environmental science. It is also different from, though closely related to, the studies of evolutionary biology, genetics, and ethology.

Ecology is a broad science which can be subdivided into major and minor subdiscipline. The major sub-disciplines include:

- **Behavioral ecology**, studies the ecological and evolutionary basis for animal behavior, and the roles of behavior in enabling animals to adapt to their ecological niches;
- **Population ecology (or autecology),** deals with the dynamics of populations within species, and the interactions of these populations with environmental factors;
- **Community ecology (or synecology),** studies the interactions between species within an ecological community;
- **Landscape ecology**, studies the interactions between discrete elements of a landscape;
- **Ecosystem ecology,** studies the flows of energy and matter through ecosystems;

Ecology can also be sub-divided on the basis of target groups: Animal ecology, Plant ecology, Insect ecology; or from the perspective of the studied biomes: Arctic ecology (or polar ecology), Tropical ecology, Desert ecology.

Other specialized branches of ecology include:

- **Chemical ecology** deals with the ecological role of biological chemicals used in a wide range of areas including defense against predators and attraction of mates;
- **Systems ecology** and biogeochemistry which focus on the flow of energy and nutrients within and among ecological units;
- **Ecophysiology** studies the relations between a single type of organism and the factors of itsenvironment;
- **Ecotoxicology** looks at the ecological role of toxic chemicals (often pollutants, but also naturallyoccurring compounds);
- **Evolutionary ecology or Ecoevolution** which looks at evolutionary changes in the context of thepopulations and communities in which the organisms exist;
- **Molecular ecology** attempts to address ecological questions at the molecular level, usually throughby looking at DNA or allozymes;
- **Palaeoecology:** to understand the relationships between species in fossil assemblages, and in so doinggain insight into the way these species might have been shaped by their interactions with other species;
- Ecology also plays important roles in many inter-disciplinary fields: ecological design and ecological engineering, ecological economics.
- **Human ecology** and ecological anthropology social ecology, ecological health and environmentalpsychology.

Finally, ecology has also inspired other non-biological disciplines such as **industrial ecology,software ecology and information ecology.**

## 4. Approaches in Ecological Studies: formulating hypothesis; theoretical ecological models; probabilistic ecological models.

**Approaches defined**

**Descriptive**–describes organisms and their interactions within ecosystems. This is the foundation ofall ecological science (explains what).

**Functional**–studies proximate causes, the dynamic responses of populations and communities toimmediate factors of environment (answers how).

**Evolutionary**–considers organisms and the relationships between organisms as historical products ofevolution (answers why).

**Domains of Ecological Research:**

| Domain | Topic | Domain | Topic |
|---|---|---|---|
| Single species | Demography | Species interactions | Mutualism |
| | Physiology | | Parasitism |
| | Behavior | Ecosystem | Food web |
| | Evolution | | Climate change |
| | Genetics | | Vegetation dynamics |
| Community | Biodiversity | | Biomass |
| | Structure | | Productivity |
| Species Interactions | Grazing | | Biogeochemical |
| | Predation | Others | Scales & Statistics |

**Formulating Hypothesis Hypothesis:**

A hypothesis can be defined as a tentative explanation of the research problem, a possible outcome ofthe research, or an educated guess about the research outcome.

**Or,**

It is a tentative prediction about the nature of the relationship between two or more variables.

**Nature of Hypothesis:**

- It can be tested – verifiable or falsifiable
- It is a prediction of consequences
- It is neither too specific nor to general
- Hypotheses are not moral or ethical questions
- It is considered valuable even if proven false

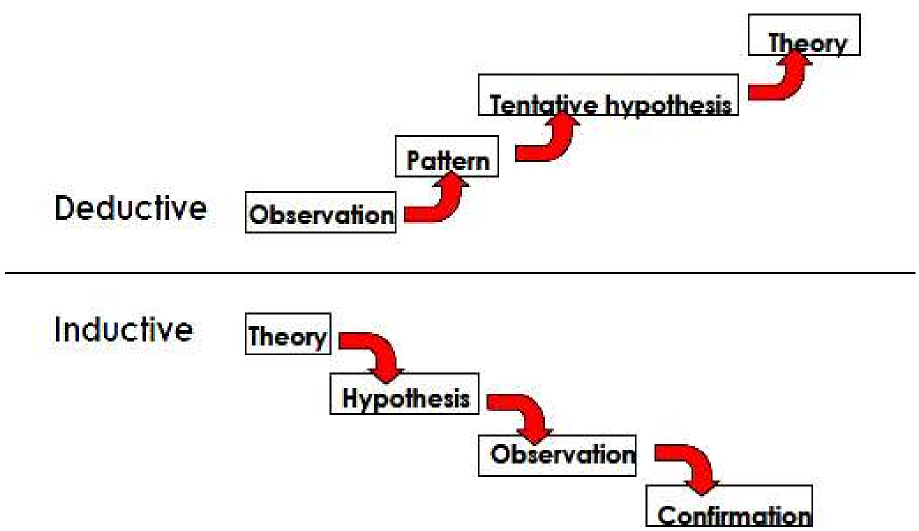
**Types of Hypotheses:**

**NULL HYPOTHESES**

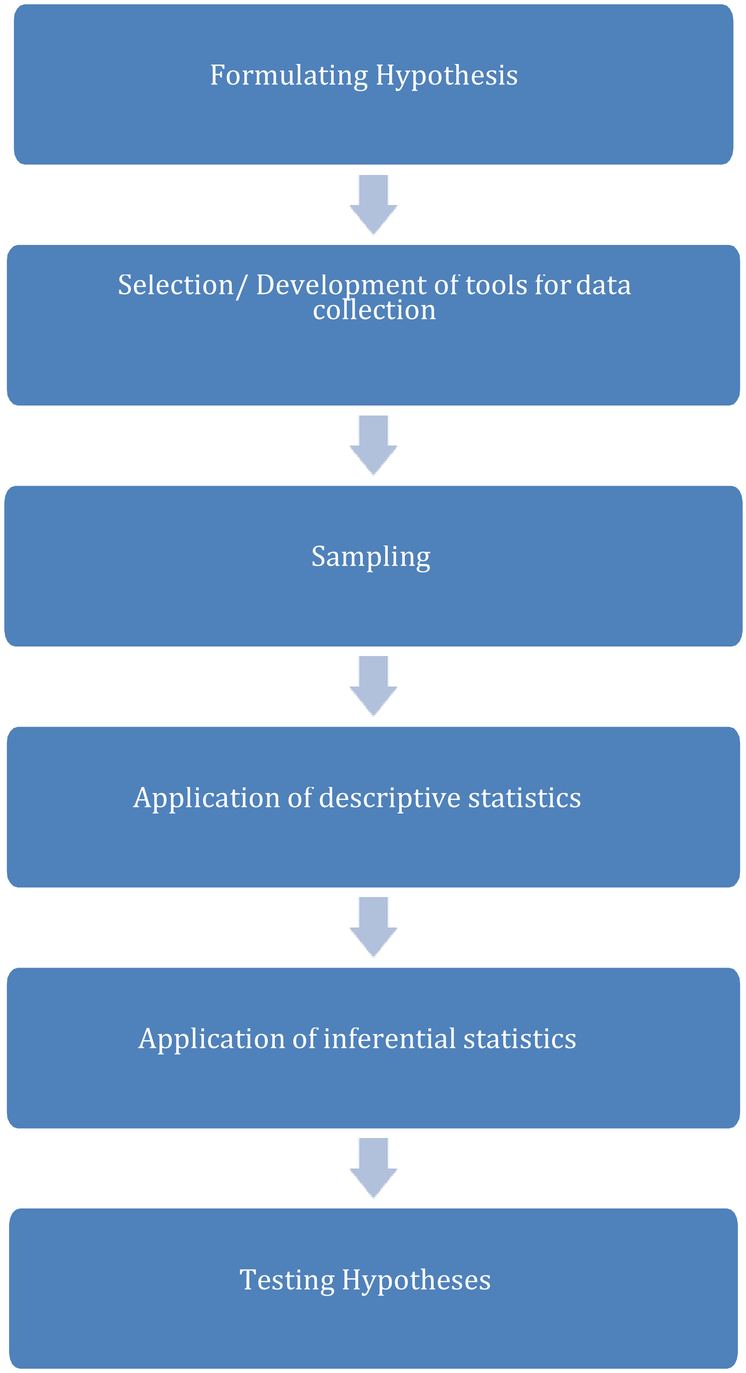
- Designated by: $\mathbf{H_0}$ or $\mathbf{H_N}$ **Alternative Hypotheses**
- Designated by: $\mathbf{H_1}$ or $\mathbf{H_A}$ **Developing Hypotheses**
- The null hypothesis represents an assumption that has been put forward, either because it is believed to be true or because it is used to be a basis for argument, but has not been proved.
- Has serious outcome if incorrect decision is made!

The alternative hypothesis is a statement of what a hypothesis test is set up to establish. Opposite of Null Hypothesis. Only reached if $\mathbf{H_0}$ is rejected.

Frequently "alternative" is actual desired conclusion of the researcher.



**Testing Hypotheses:**



Descriptive statistics: mean, median, S.D.

**Nothing happened**: **Null hypothesis is accepted**

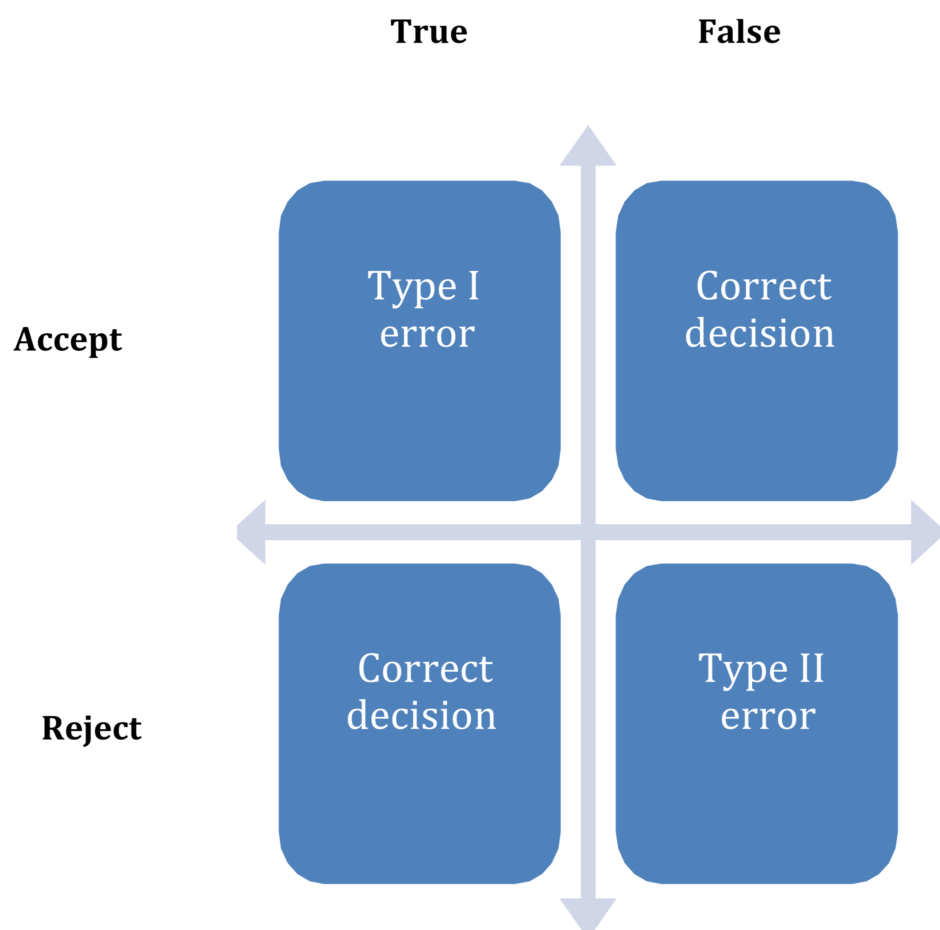
(There is no significant relationship between X and Y)

**Something happened**: **Alternative hypothesis is accepted**

(There is significant relationship betweenX and Y)

**Errors in hypotheses testing:**

**Null Hypothesis**




**Theoretical Ecological Models:**

- ❖ The complexity of the natural world can make the development of null hypothesis difficult.

- ❖ It is the interconnections between the different components of nature that often give any natural system its distinct characteristics. These inter-connections are manifested in the transfer of materials, transformation of energy, feeding relationships, social interactions….
- ❖ So simple statements/questions may not lead directly to simple hypothesis, because of this many hypotheses in ecology emerge first through the development of theoretical models that explain the interactions of the variables of complex systems.
- ❖ Theoretical Ecological Models are verbal, algebraic, or graphic constructions that identify the relationships between variables of a system.
- ❖ A simple hypothesis can be considered a theoretical model in its simplest form: The fruits of genus 'A' dehisce on warm mornings following continuous rain days. This can be represented as a simple mathematical expression –

$$y = ax + b$$

**Experimental Approach:**

- An experiment is an activity whereby natural processes are allowed to proceed underconditions that are controlled by the experimenter.
- The goal of an experiment is to make an inference about a null hypothesis, that is to determinewhether it is more likely that the null hypothesis is true or false.
- If the conclusion is that the null hypothesis is false then some alternative hypothesis must betrue.
- Properly designed experiments control to certain extent the possibilities of Type I and Type IIerrors.
- Experimental studies involve the application of treatments and the observation of responses.

**Probabilistic Ecological Models:**

- ✓ Probabilistic Ecological Models deal with the statistical probability of occurrence of certainphenomenon.

- ✓ Probabilistic Models are based on the exact knowledge of the most desirable information.

- ✓ By definition, there are three conditions that must be satisfied to make a prediction in ProbabilisticModels – flawless models are required to characterize the event of interest, assumptions must be honored all model parameters must be known
- ✓ Purely deterministic model has no stochastic part producing different results under stable conditions and allow reasonable extrapolation beyond the available sampling.

**Statistical Approaches:**

Statistical approaches provide the means of understanding a process with some specified level of uncertainty. In statistics, an unknown true characteristic of a system is called a parameter. The parameters of ecological systems are usually unknowable but when the values are obtained by direct observations or measurement statistical analyses are not required. A parameter is estimated by a statistic, which is some value or index calculated from a sample of measurements of the variable that is obtained from the entire group of possible measurements of that variable.

Ideally, once the ecological question has been identified, the study is designed and the data is collected in a manner that will result in strong inferences. There are many important aspects to the collection of ecological data relating to study design and sampling method that will influence the type and strength of statistical inferences that can made: identifying the desired scope of inference, choosing appropriate observational/experimental units, choosing the types of data to collect, and establishing a robust sampling scheme (i.e., spatial and/or temporal distribution of units and method(s) of collecting the data) to ensure accurate and precise inferences.

We usually wish to make inferences about a population (statistical, not biological), which is defined as the collection of all the possible observations of interest. A biological population under consideration may or may not constitute the statistical population if, for example, the functional population extends over a broader geographic extent than the study area. We usually represent the size of the statistical population in statistical formulae as upper case N. For lots of practical reasons, we usually collect only a subset of observations from the population, and we represent the size of the sample as lower case **n**. Importantly, we infer characteristics of the population from the sample; e.g., estimate parameters, test hypotheses, compare models, and make predictions. Thus, the entire realm of inferential statistics applies when we seek to draw conclusions from a sample about the underlying population. Otherwise, we may be interested in or forced to merely describe the patterns in the sample without explicit inference to the population – the realm of descriptive statistics. Note, in rare cases, we may actually observe every possible entity of interest – the population – in which case simple descriptive statistics suffice to draw conclusions from since we know with exactness (to the precision of our measurement system) the characteristics of the population we are studying.

Once we have identified our ecological question, the first thing we need to do is determine what data to collect. This is one of the most important steps in the entire modeling process, because if we collect the wrong type of data, no statistical model of any kind will allow us to answer our ecological question. While there are many important considerations to this step, we need to carefully consider the number and types of variables to collect and their relationships. In ecological studies, there are several major types of data: continuous data counts proportions binary data time at death time series circular data. And there are at least three major types of variables based on their relationships to each other: independent variables dependent variables interdependent variables.

## 5. Introduction to Climatology: Atmospheric variables, Remote Sensing, Climate Diagrams.

**Atmosphere:** The atmosphere is a dynamic collection of gases that constantly move and change. These gases form several layers around Earth that are loosely defined by composition and temperature. Working from the surface of the Earth outward, the layers are:

- the **troposphere**, which extends to an altitude of about 8 kilometres in polar regions and 17 kilometres at the equator;
- the **stratosphere**, which extends to about 50 kilometres from Earth's surface;
- the **mesosphere**,which extends to 80 or 90 kilometres from Earth's surface; and
- the **thermosphere** (also called the ionosphere), which gradually diminishes and forms a fuzzy border with outer space.

There is relatively little mixing of gases between layers. The atmosphere is a soup of chemicals. About seventy-eight per cent of the soup is nitrogen and twenty-one per cent is oxygen. The remaining one per cent is a mix of the other gases, which play an important role in the health of the ecosystem.

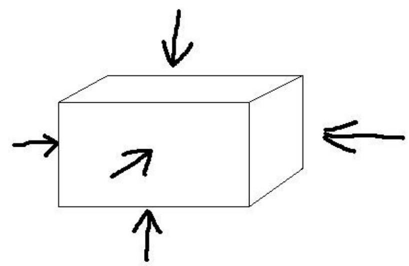
We move through this gaseous soup every day, pushing aside or breathing in billions of its molecules. These molecules are not static—they are constantly interacting with each other in ways that can create new chemicals, and they are also interacting with the land, the sea, plants, and animals.

**Atmospheric variables:**

In a moist atmosphere, generally there is a necessity of three variables to specify the state. They may be taken, for example, to be **temperature, pressure, and water vapor pressure**.

But **Temperature, humidity, precipitation, air pressure, wind speed, and wind direction** are the key observations of the atmosphere that help forecasters predict the weather.

- **Temperature –** a measure of the kinectic energy of molecules – heat content of atmosphere or earth's surface.
- **Humidity –** moisture content of the atmosphere or how close it is to saturation.
- **Precipitation –** supply of water substance from atmosphere-rain-snow-hail precip. Is very discontinuous in space.
- **Wind –** air in motion – it is a vector having both magnitude (wind speed) and direction (600 – 1200 - 3000 )
- **Pressure –** Force per unit area – or weight of an air column per unit area.



Horizontal pressure differences accelerate winds.

**Remote Sensing**

Remote sensing as a tool opened up new vistas of perception of things that exist too far or on extensive spatial scales. Nowadays there is a big assortment of satellite systems actively recording information about the Earth. A wide variety of imagery is available from satellites which collect a large amount of information about the earth's surface every day. Each of the systems varies in terms of their spatial, spectral, radiometric and temporal resolution. Those characteristics play an important role in defining which applications the sensor is best suited for. Remote sensing data has shown tremendous potential for applications in various field for example in land use mapping and detection, geologic mapping, water resource applications (pollution, lake-eutrophication assessment), wetland mapping, urban and regional planning, environment inventory, natural disaster assessment or archaeological applications and other.

## 1. Application in Agriculture

Agriculture plays an important role in economies of countries. The production of food is important to everyone and producing food in a cost-effective manner is the goal of every farmer and an agricultural agency. The satellites have an ability to image individual fields, regions and counties on a frequent revisit cycle. Customers can receive field-based information including **crop identification, crop area determination and crop condition monitoring** (health and viability). Satellite data are employed in precision agriculture to manage and monitor farming practices at different levels. The data can be used to farm optimization and spatially-enable management of technical operations. The images can help determine the location and extent of crop stress and then can be used to develop and implement a spot treatment plan that optimizes the use of agricultural chemicals. The major agricultural applications of remote sensing include the following:

- crop type classification
- crop condition assessment (crop monitoring, damage assessment)
- crop yield estimation
- mapping of soil characteristics
- mapping of soil type
- mapping soil erosion & erosion vulnerability
- mapping soil management practices
- compliance monitoring (farming practices)

**Crop type classification**

Remote sensing technology can be used to prepare maps of crop type and delineating their extent. Traditional methods of obtaining this information are census and ground surveying. The use of satellites is advantageous as it can generate a systematic and repetitive coverage of a large area and provide information about the health of the vegetation. The data of crop is needed for agricultural agencies to prepare an inventory of what was grown in certain areas and when. This information serves to predict grain crop yield, collecting crop production statistics, facilitating crop rotation records, mapping soil productivity, identification of factors influencing crop stress, assessment of cropdamage and monitoring farming activity.

**Crop monitoring and damage assessment**

Remote sensing has a number of attributes that help in monitoring the health of crops. Remote sensing imagery also gives the required spatial overview of the land. Remote sensing can aid in identifying crops affected by conditions that are too dry or wet, affected by insect, weed or fungal infestations or weather related damage. Images can be obtained throughout the growing season to not only detect problems, but also to monitor the success of the treatment. Detecting damage and monitoring crop health requires high-resolution, multi- spectral imagery and multi-temporal imaging capabilities

## 2. Application in Forest mapping

One of the basic applications is forest cover typing and species identification. Forest cover typing can consist of exploration mapping over a large area, while species inventories are highly detailed measurements of stand contents and characteristics (tree type, height, density). Using remote sensing data we can identify and delineate various forest types that would be difficult and time consuming using traditional ground surveys. Data is available at various scales and resolutions to satisfy local or regional demands. For mapping differences in forest cover we require the following:

- Multi-spectral images, a very high resolution data is required to get detailed speciesidentification;
- Multi-temporal images datasets contribute phenology information of seasonal changes ofdifferent species;
- Stereo photos help in the delineation and assessment of density, tree height and species;
- Hyper-spectral imagery can be used to generate signatures of vegetation species and certain stresses (e.g. infestations) on trees. Hyper-spectral data offers a unique view of the forest cover, available only through remote sensing technology;

- RADAR is more useful for applications in the humid tropics because its all weather imaging capability is valuable for monitoring forest.

**Clear cut mapping and deforestation**

One of an important global problem is deforestation. There are many implications of it: in industrialized parts of world, pollution (acid rain, soot and chemicals from factory smoke plumes) has damaged a large percentage of forested land, in tropical countries, valuable rainforest is being destroyed in an effort to clear potentially valuable agricultural and pasture land. The loss of forests increases soil erosion, river siltation and deposition, affecting the environment.

## 3. Application in Land cover Mapping

Land cover mapping is one of the most important and typical applications of remote sensing data. Land cover corresponds to the physical condition of the ground surface, for example, forest, grassland, concrete pavement etc., while land use reflects human activities such as the use of the land, for example, industrial zones, residential zones, agricultural fields etc. Initially the land cover classification system should be established, which is usually defined as levels and classes. The level and class should be designed in consideration of the purpose of use (national, regional or local), the spatial and spectral resolution of the remote sensing data, user's request and so on.

**Land cover change** detection is necessary for updating land cover maps and management of natural resources. The change is usually detected by comparison between two multi-date images, or sometimes between an old map and an updated remote sensing image.

- **seasonal change**: agricultural lands and deciduous forests change seasonally.
- **annual change**: land cover or land use changes, which are real changes, for example deforested areas or newly built towns.

Information on land cover and changing land cover patterns is directly useful for determining and implementing environment policy and can be used with other data to make complex assessments (e.g. mapping erosion risks).

**Advantages:**

- ✓ Fully automated thus require only an occasional technician.
- ✓ Excellent coverage (horizontally) even over oceans.

**Disadvantages:**

- Does not measure state variables directly. They must be inferred or retrieved.
- In the case of satellites, poor vertical resolution.
- Expensive.

**Climate:**

Atmospheric science is often divided into three specific fields of interest:

- ➢ **Aerology:** It is essentially the study of the free atmosphere through its vertical extent.
- ➢ **Meteorology:** It deals with the motions and phenomena of the atmosphere to forecastweather and explain the processes involved.
- ➢ **Climatology:** It is the study of atmospheric conditions over periods of time measured inyears or more.

**Weather** is the day-to-day state of the atmosphere, and its short-term (minutes to weeks) variation.

It describes the atmospheric conditions at a specific place at a specific point in time. Weathergenerally refers to day-to-day temperature and precipitation activity.

It refers to real-time measurements of atmospheric pressure, temperature, wind speed and direction,humidity, precipitation, cloud cover, and other variables.

**Climate** is defined as statistical weather information that describes the variation of weather at a givenplace for a specified interval.

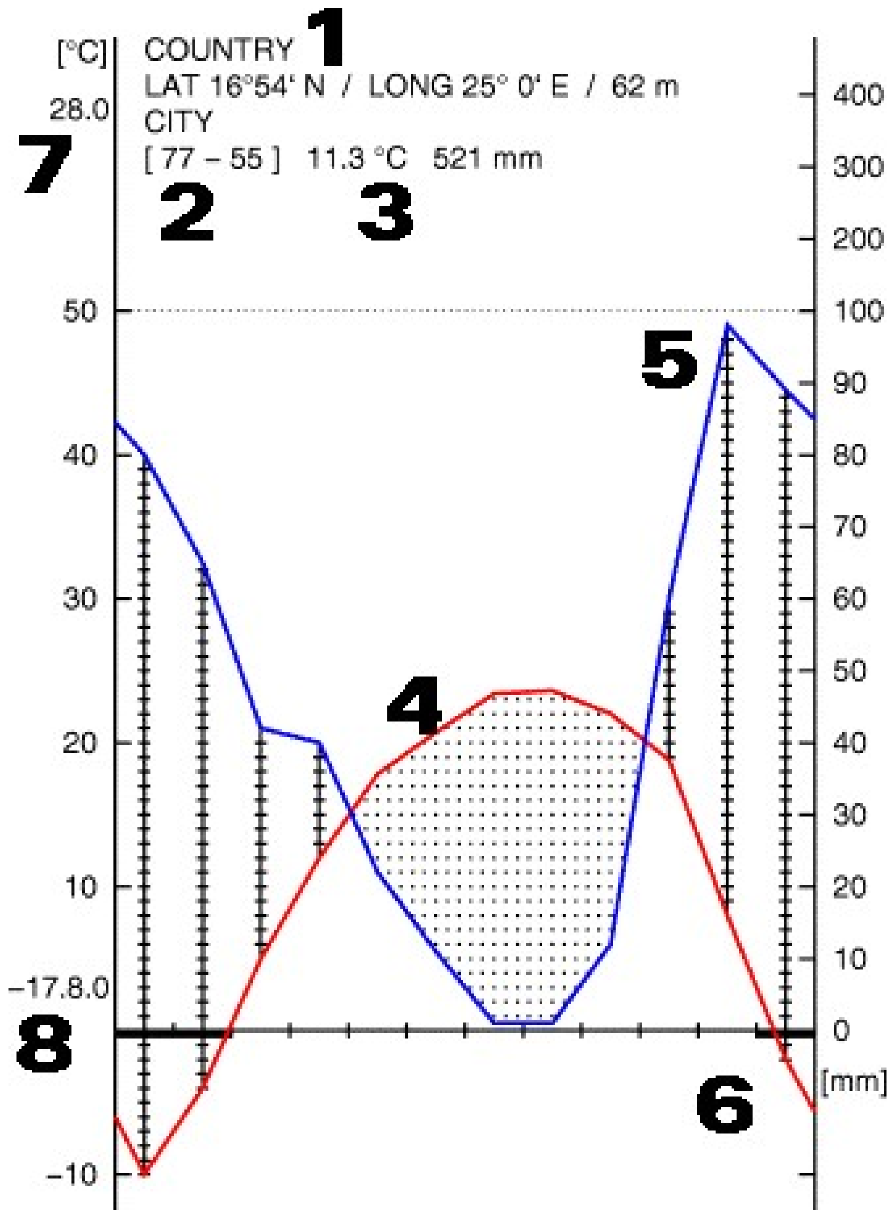
It describes the average conditions expected at a specific place at a given time. It implies aggregatesof weather statistics over periods of minimum 30 years.

**Elements of Climatology:**

- Assessment of the effect of climate on the natural environment, agricultural production, energy supply and demand, land & water resources, transportation, human health &national security.
- Basic & applied research to improve the understanding of climatic processes – natural and human-induced.
- Social, economic and political implications of climate change.
- Methods for improving climate forecasts.
- Global data collection on continued basis.
- Measures for increasing international cooperation in climatology.

**Climate Diagrams:**

Climate diagrams are brief summaries of average climatic variables and their time course. They have proven useful for a wide range of sciences, industry, teaching & are useful for planning and design. In bio- and geosciences, they are used as an instrument to show the relationships between soil, vegetation, and climate. In agronomic sciences, they are used to indicate the range for crops. They indicate optimal travel schedules for the tourism industries. The diagrams display monthly averages for temp. and precipitation over a year. Each mark along the horizontal line indicates a month. The diagrams start with January in the left corner of the diagram for the northern hemisphere and with July for the southern hemisphere respectively. Thus, the astronomic summer is always shown in the middle of the diagram. 20 mm of monthly precipitation (right ordinate) equals 10°C average temperature (leftordinate). When the precipitation curve undercuts the temperature curve, the area in between them is dotted (every 2 mm) indicating dry season. When the precipitation curve supersedes the temperature curve, vertical lines are plotted for each month (with tic marks every 2 mm) indicating moist season. A very important ecological variable is frost. The diagram shows daily average minimum temperatures below zero in black bars below the horizontal line. All diagrams are designed in a uniform pattern.




1. Country name, station location and elevation, station name

2. Period of observation of temperature (77 years) and precipitation (55 years)

3. Annual average of temperature and annual precipitation sum 4 (red) Temperature curve 5 (blue) Precipitation time series 6 Indication of frost periods 7 Mean daily max. temperature of the warmest month 8 Mean daily min. temperature of the coldest

month.

**Climate Determinants:**

- Air Temperature
- Barometric Pressure
- Cloud type, height and amount
- Prevailing weather
- Dew Point temperature
- Precipitation
- Sunshine
- Wind velocity & direction

**Climate: Scales of Study**

- **MICROCLIMATE:** Characterized by climate that may extend horizontally from less than 1 meter to 100 mts and vertically from the surface upto 100 metres.
- **LOCAL CLIMATE:** Comprises of number of microclimatic areas that make up a distinctive group and horizontal dimensions extend from100 to 10,000 mts and vertically upto 1000 mts.
- **MESOCLIMATE:** Ranges horizontally from 100 – 20,000 mts. And vertically upto 6,000 mts. A great variety of individual landscapes are considered.
- **MACROCLIMATE:** Extends horizontally for distances more than 20,000 mts and vertically to heights above 6,000 mts. Such areas can be continental in extent.

## 6. Abiotic and Biotic Environment: variables in action; influence of abiotic environment on distribution and abundance of plants; levels of organization of organisms in ecology.

**Abiotic Environment:**

Ecological relationships are manifested in physicochemical environment. Abiotic component of ecosystem includes basic inorganic elements and compounds, such as soil, water, oxygen, calcium carbonates, phosphates and a variety of organic compounds (by-products of organic activities or death).

It also includes such physical factors and ingredients as moisture, wind currents and solar radiation. Radiant energy of sun is the only significant energy source for any ecosystem. The amount of non- living components, such as carbon, phosphorus, nitrogen, etc. that are present at any given time is known as standing state or standing quantity.

These factors include the non-living physiochemical factors of the environment. **Abiotic factors** are asfollows:

(i) **Inorganic substances:** Inorganic substances like carbon, nitrogen, oxygen, water, carbon di-oxide, calcium, phosphorus and their inorganic compounds. These are available as free form or dissolved in water and may be adsorbed on the soil particles.

(ii) **Organic compounds:** These are carbohydrates, proteins, lipids, nuceltic acids etc.This material is present in dead organic matter. These are broken into the simple compounds by decomposers in ecosystem for recycling of matter.

(iii) **Climatic factors:** These are factors present in the environment such as temperature, humidity, light, wind, rainfall an atomospheric gaseous etc.

The climatic factors are as follows:

1. **Temperature:**

Temperature is an ecological abiotic factor. It is a form of energy and is called the thermal energy. It penetrates into each and every region of the biosphere and affects all forms of life. It influences the various stages of life activities such as growth, metabolism, reproduction, movement, distribution, behaviour, death, etc.

Temperature is usually measured in Fahrenheit or Centigrade. The biosphere obtains its thermal energy from the Sun in the form of solar radiation. It is a variable factor. It varies from place-to-place and time-to-time. It is high in the day and at night it is low. It is high at the sea level and low at high altitudes. It is high at the equator and low in the Polar Regions. It is more in the terrestrial habitat and low in the aquatic habitat. The maximum temperature recorded on land is 85°C as in the desert and the lowest temperature is about – 70°C as in Siberia.

**Temperature Fluctuations:**

The temperature is high during daytime and low at night. This is called diurnal variation. The temperature on land is high at the sea level, but low at high altitudes. Approximately, an increase in altitude of 150 m results in a decrease in 1°C temperature. On land, maximum temperature is found along the equator. It gradually decreases towards the poles. Temperature varies according to the season. The temperature reaches its maximum during summer, while it is minimal during winter.

Temperature fluctuation in aquatic habitat is less than that of terrestrial habitat.

**Thermal Stratification:**

In lakes and ponds a gradual decrease in temperature from the surface to the bottom is seen. This leads to different layers of water with different temperatures. The arrangement of different layers based on temperature differences is called thermal stratification.

**Biological Effects of Temperature:**

- **Eurythermal and Stenothermal Organisms:**

Organisms that can tolerate wide range of temperature fluctuations are called eurythermal organisms, e.g. man, lizard, amphibians. Those that cannot tolerate wide range of temperature fluctuations arecalled stenothermal organisms, e.g. corals, snails

- **Poikilothermic and Homeothermic Animals:**

Animals in which the body temperature changes according to the fluctuations in the environmental temperature are called poikilothermic or cold-blooded animals or ectotherms. During cold, the body temperature also drops. For example, all animals except birds and mammals.

In birds and mammals, the body temperature remains constant and is not dependent on environment temperature. These animals are called homeotherms or warm blooded or endotherms. When the environment temperature drops the animal maintains its temperature by metabolic activities.

**Effect of Temperature on Growth and Development:**

Temperature affects growth and development of animals. For example, the oyster, Ostraea virginica grows to 1.4 mm when it is reared at 10°C, but when reared at 20°C it grows to 10.3 mm. Similarly, the eggs of the mackerel fish does not develop below 8°C and above 25°C. Low temperature prevents metamorphosis in salamanders and makes the animal neotenous.

**Effect of Temperature on Morphology:**

The morphological characters of organisms are altered by temperature. Temperature influences the size of animals and the relative proportions of the parts of the body. Three rules have been put forth to understand how the temperature influences various characteristic features.

a. **Bergman's Rule:**

The mammals in colder areas are larger is size than in warmer climates. This is called the Bergman's rule. For example, the penguins found in Antarctica attain a body length of 100- 200cm, whereas the penguins of equatorial Galapagos Islands are about 49cm long.

**b. Allen's Rule:**

According to Allen's rule, extremities of the mammals, like the tail, snout, ears and legs are relatively shorter in colder regions than in warmer regions. In the Arctic rabbit the ears are shorter, while in the Californian rabbit, the ears are longer.

The explanation in both the cases is that endothermic organisms in colder climates should have smaller surface area relative to volume across which they lose heat. Allen's rule has widespread applicability when compared to Bergman's rule because of number of factors that affect body size, though it is true at an intra-specific level.

**c. Gloger's Rule:**

According to Gloger's rule the animals in the tropic are darker and heavily pigmented than their counterparts of the colder and dry regions.

**Effect of Temperature on Distribution:**

Temperature is a limiting factor on the distribution of animals. The distribution of warm-blooded animals is not affected by temperature. But cold-blooded animals are abundant in tropical and temperate regions, and their number rapidly diminishes towards the poles.

**Effect of Temperature on Plants:**

- The opening of the flowers of various plants during the day and night is often due to temperature difference between the day and night.
- The seed of some plants (biennials) normally germinate in the spring or summer. These seeds require a cold treatment of winter. This is called vernalisation. Vernalisation can be induced in seeds artificially. This adaptation ensures that seeds do not germinate during autumn, but only after winter, when the seedlings have better chances to survive.
- Deciduous trees lose their leaves in winter and enter into a state of dormancy, where the buds are covered for protection against the cold.
- In the desert due to great temperature variation between day and night organisms exhibit distinct periods of activity, e.g. many cacti flower at night are

pollinated by nocturnal insects. Cactus is among the most drought-resistant plants on the planet.

**In a cactus:**

i. Leaves are modified into spines. These spines protect the plant from animals, shade it from the Sunand also collect moisture. This also reduces transpiration.

ii. Extensive shallow root systems that are spread out just below the surface to allow the plant toabsorb water immediately as it rain.

iii. Succulent stems have the ability to store water. This enables the cacti to survive in dry climate and can survive years of drought on the water collected from a single rainfall.

iv. Waxy skin to seal in moisture.

v. Cacti depend on chlorophyll in the outer tissue of stems to conduct photosynthesis for themanufacture of food.

vi. Cacti close their stomata during the day and open them at night to reduce transpiration. These plants exhibit the CAM pathway of photosynthesis. Many other desert trees and shrubs have also adapted by eliminating leaves – replacing them with thorns, not spines, or by greatly reducing leaf size to eliminate transpiration. Many xerophytes may accumulate proline in the cells of its leaves to maintain osmotic and water potential. Chaperonins, the heat shock proteins provide physiological adaptations to plants to high temperatures. These proteins maintain the structures and avoid denaturation of other proteins.

vii. Plants living in cold climates can tolerate frost conditions. When the temperature drops the plant becomes dormant and exhibits slow rate of photosynthesis and respiration. Antifreeze proteins are found in some plants which avoid chilling and frost damage by increasing their sugars and alcohols to lower the freezing point of cell fluids. This causes super cooling of the cell sap for short periods of time without causing freezing.

**Structural Adaptations in a Camel:**

In hot deserts, temperature is very high. To escape from the heat desert animals have the different adaptations for resistance to heat. This can be understood from the adaptations of a camel: All desert dwellers have adapted to conserve water, food and energy. The camel is one of the best survivors in the desert and it is rightly called the 'ship of the desert' because it is adapted very well to the conditions of the desert.

2. **Light:**

Light is the most important and indispensable physicochemical, abiotic ecological factor without which life cannot exist. Organisms get light from the Sun, Moon, stars, lightning, volcanoes and bioluminescent organisms. Among this light energy from the Sun is the most important in nearly all ecosystems. It is the energy that is used by green plants (which contain chlorophyll) during the process of photosynthesis; a process during which plants manufacture organic substances by combining inorganic substances.

The energy from the sun comprises of short, high-energy radiations to long, low energy radiations. The amount of energy in the sunrays just before entering the atmosphere is about 2 cal/cm$^2$/min. It is called solar constant. As the sunrays travel through the atmosphere a large amount of energy is absorbed.

**Biological Effects of Light:**

- **On Metabolism:**

High intensity of light increases metabolic activity in animals by increasing enzyme activity.

- **On Pigmentation:**

Light induces photochemical reactions in the formation of colour pigments called melanophores.Animals living in cave, bottom of the ocean do not possess colour.

- **Protective Coloration:**

Animals develop colour patterns to conceal themselves from predators to bend with the surroundings.For example, the leaf insect, Phyllium is green in colour.

- **Colour Change in Animals:**

The Chamaeleon is able to change its colour according to its background. This happens because of thedistribution of the melanophores depending on the light entering the eye.

- **Vision:**

Light enables organisms to see objects in the environment where it is found. Animals possess specific organs to 'see' like the eyespots in protozoa, compound eyes in insects and crustaceans, eyes in vertebrates etc. Animals that live in habitats where there is dim light have large eyes that are powerful as in the owls and loris. In animals that live in habitat where there is no light, the eyes are reduced.

- **Reproduction:**

Animals are classified into the following categories according to the influence of light on reproduction:

- **Long-Day Animals:**

This group of animals are sexually active when the days are long, e.g. birds.

- **Short-Day Animals:**

This group are sexually active when the days are short, e.g. sheep, deer, goats.

- **Day-Neutral Animals:**

In this group reproduction is influenced by light, e.g. man, cow.

- **Diurnal Migration:**

In the oceans, planktons  move to the surface in the early morning and evenings and move to the deeper parts of the ocean when there is high intensity. This movement is called diurnal migration.

- **Circadian Rhythm:**

The daily rhythm in synchrony with the rotation of the earth is called circadian rhythm. This is endogenous, i.e. initiated by internal factors and is due to a biological clock present in organism. For example, many plants show rhythm of their leaves for sleep. They close or droop during night time and open at daytime. Sleeping and waking in man follow circadian rhythm.

**Adaptations of Plants to Changing Light Conditions:**

Light requirements of plants differ and as a result distinct layers or stratification can be observed in an ecosystem. Plants which grow well in bright sunlight are called heliophytes (Greek helios, sun) and plants which grow well in shady conditions are known as sciophytes (Greek skia, shade).

Heliophytes have a high rate of respiration and are adapted to high light intensities, while sciophytes have low rate of photosynthesis, respiration, metabolism and growth.

**3. Water:**

Water covers 70% of the earth's surface and is found as vapour in the atmosphere and in the soil as soil water. 97% of the water is found in the oceans and 3% is found as freshwater. Approximately 70% of freshwater is found as ice caps and glaciers, 20% as underground water while the remaining is found in lakes, streams and rivers. Water is essential for life and all organisms depend on it to survive in especially desert areas.

The Water Cycle in Nature:

Water cycles through the biosphere and is constantly exchanged between the physical and the biotic environment. The circulation of water that does not involve living organism is the global water cycle and that which involves living systems is the biological water cycle.

**Adaptations of Plants in Water:**

Water constitutes the hydrosphere and includes both fresh and seawater. Aquatic plants are called hydrophytes. These plants possess specialised parenchyma called aerenchyma that possesses air filled spaces in the leaves and stem. This enables the plants to float.

**Adaptations of Animals in Aquatic Habitat:**

A number of animals live in the aquatic medium, i.e. water. There are animals that are found exclusively in the fresh water, while there are some that are found living in the marine environment; there are some that are capable of living in both fresh and marine water. A few examples of animals that are aquatic are vertebrates like fish, mammals (whales, dolphins, seals, sea lions, etc.), invertebrates like starfish, prawns, lobsters, octopus, oysters, etc.

Adaptations in animals living in water are called aquatic adaptations and organisms living in water are called aquatic organisms. Aquatic organisms found on the surface of the water are called pelagic organisms for which they possess special adaptations. Similarly organisms living in the deep sea, called benthic animals are adapted to live in such conditions.

**4. Air:**

Air or atmosphere is the gaseous envelope that surrounds the lithosphere and hydrosphere. The atmosphere is a mixture of gases. Nitrogen makes up four-fifths of it and oxygen makes up a little more than one-fifth. Small quantities of other gases like argon, neon, helium, krypton, xenon, carbon dioxide, hydrogen and ozone are also found.

The most important gases used by plants and animals are oxygen, carbon dioxide and nitrogen.

**i. Oxygen:**

Oxygen is used by all living organisms during respiration.

**ii. Carbon Dioxide:**

Carbon dioxide is used by green plants during photo-synthesis.

**iii. Nitrogen:**

Nitrogen is made available to the plants by certain bacteria and through the action of lightning.Layers of the Atmosphere are –

The atmosphere is made of five or more dis¬tinct layers that differ in density, temperature,composition and properties.

a. Troposphere – 0-10 kms
b. Stratosphere – 10-40 kms
c. Mesosphere – 40-70 kms
d. Thermosphere – 70-400 kms
e. Exosphere – 400 kms and beyond

**5. Wind:**

Differential solar radiation in different regions of the Earth as well as rotation of the Earth causes air to move and form wind. Depending upon the velocity of the wind it is called breeze, gale, storm or hurricane. Dust storms and squall are also modified forms of wind; the former carries dust particles while the latter carries rain or snow.

Winds or air currents arise on a world-wide scale as a result of a complex interaction between hot air expanding and rising (convection) in the mid-latitudes. This has various effects on the rotation of the Earth and results in a centrifugal force which tends to lift the air at the equator. This force is known as the Coriolis force and tends to deflect winds to the left of the southern hemisphere and to the right in the northern hemisphere. Winds carry water vapour, which may condense and fall in the form of rain, snow or hail.

Wind plays a role in pollination and seed dispersal of some plants, as well as the dispersal of some animals, such as insects. Wind erosion can remove and redistribute topsoil, especially where vegetation has been reduced. Warm berg wind results in desiccation, which creates a fire hazard. If plants are exposed to strong prevailing winds are they usually smaller than those in less windy conditions.

**Biotic Environment:**

The biotic components include all living organisms present in the environmental system. From nutrition point of view, the biotic components can be grouped into two basic components:

i. Autotrophic components, and
ii. Heterotrophic components

The autotrophic components include all green plants which fix the radiant energy of sun and manufacture food from inorganic substances. The heterotrophic components include non-green plants and all animals which take food from autotrophs.

So biotic components of an ecosystem can be described under the following three heads:

1. Producers (Autotrophic components),
2. Consumers, and
3. Decomposers or reducers and transformers

The amount of biomass at any time in an ecosystem is known as standing crop which is usually expressed as fresh weight, dry weight or as free energy in terms of calories/metre.

**Producers (Autotrophic elements):**

The producers are the autotrophic elements—chiefly green plants. They use radiant energy of sun in photosynthetic process whereby carbon dioxide is assimilated and the light energy is converted into chemical energy. The chemical energy is actually locked up in the energy rich carbon compounds. Oxygen is evolved as by-product in the photosynthesis.

This is used in respiration by all living things. Algae and other hydrophytes of a pond, grasses of the field, trees of the forests are examples of producers. Chemosynthetic bacteria and carotenoid bearing purple bacteria that also assimilate CO2 with the energy of sunlight but only in the presence of organic compounds also belong to this category.

The term producer is misleading one because in an energy context, producers produce carbohydrate and not energy. Since they convert or transduce the radiant energy into chemical form, E.J. Kormondy suggests better alternative terms 'converters' or 'transducers'. Because of wide use the term producer is still retained.

**Consumers:**

Those living members of ecosystem which consume the food synthesized by producers are called consumers. Under this category are included all kinds of animals that are found in an ecosystem.

There are different classes or categories of consumers, such as:

(a) Consumers of the first order or primary consumers,

(b) Consumers of the second order or secondary consumers,

(c) Consumers of the third order or tertiary consumers, and

(d) Parasites, scavengers and saprobes.

**(a) Primary consumers:**

These are purely herbivorous animals that are dependent for their food on producers or green plants. Insects, rodents, rabbit, deer, cow, buffalo, goat are some of the common herbivores in the terrestrial ecosystem, and small crustaceans, molluscs, etc. in the aquatic habitat. Elton (1939) named herbivores of ecosystem as "key industry animals". The herbivores serve as the chief food source for carnivores.

**(b) Secondary consumers:**

These are carnivores and omnivores. Carnivores are flesh eating animals and the omnivores are the animals that are adapted to consume herbivores as well as plants as their food. Examples of secondary consumers are sparrow, crow, fox, wolves, dogs, cats, snakes, etc.

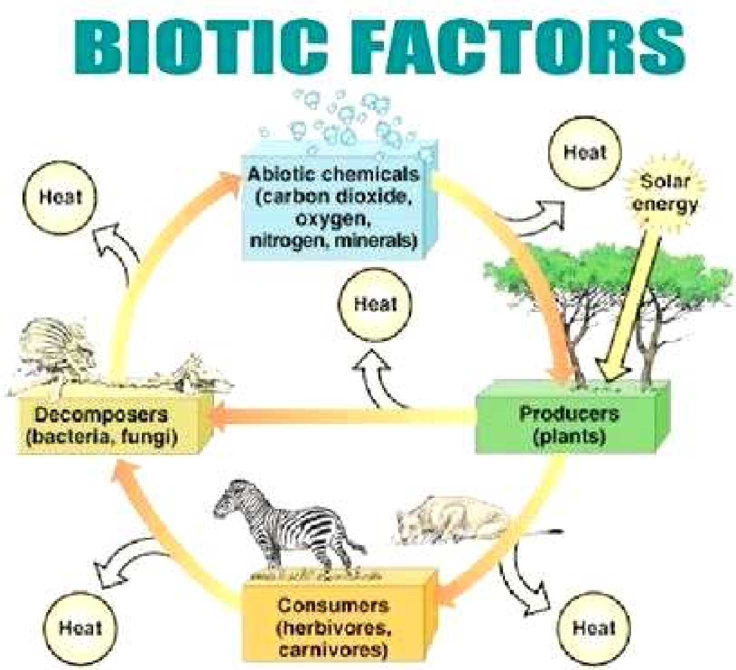
**(c) Tertiary consumers:**

These are the top carnivores which prey upon other carnivores, omnivores and herbivores. Lions, tigers, hawk, vulture, etc. are considered as tertiary or top consumers.

**(d)** Besides different classes of consumers, the parasites, scavengers and saprobes are also included in the consumers. The parasitic plants and animals utilize the living tissues of different plants and animals. The scavengers and saprobes utilize dead remains of animals and plants as their food.

**Decomposers and transformers:**

Decomposers and transformers are the living components of the ecosystem and they are fungi and bacteria. Decomposers attack the dead remains of producers and consumers and degrade the complex organic substances into simpler compounds. The simple organic matters are then attacked by another kind of bacteria, the transformers which change these organic compounds into the inorganic forms that are suitable for reuse by producers or green plants. The decomposers and transformers play very important role in maintaining the dynamic nature of ecosystems.



**Effects of Biotic Factors on Vegetation:**

Any activity of the living organism which may cause marked effects upon vegetation in any way is referred to as biotic effect. The biotic effect may be both direct and indirect. It may be beneficial to the plants in some respects but detrimental in other respects.The biotic effects modifying the vegetation can be discussed in the following heads:

1. Interactions between the plants and local animals and man.
2. Interaction among plants growing in a community.
3. Interaction between plants and soil microorganisms.

**1. Interaction between Plants and Local Animals and Man:**

These can be described under the following heads:

(i) Effects of grazing and browsing by animals.
(ii) Role of animals in the pollination.
(iii) Role of animals in the dispersal of seeds and fruits.
(iv) Insects and carnivorous plants.
(v) Effects of human activities on vegetation.
(vi) Myremecophily.

***(i) Effects of grazing and browsing:***

Grazing means eating away of un-harvested herbs as forage by animals, as for example, eating away of grasses by goats whereas browsing refers to a similar use of shrubs or trees by animals, as for example, eating away of leaves and small twigs of *Margosa* (Neem) by camels.

The animals destroy a large part of Vegetation by grazing and browsing. Some animals prefer to grazeand browse on some particular plant species they show selective grazing and browsing, e.g., sheep normally prefer forbs, horses and cattle prefer grasses and goats and deer prefer woody and leafy Parts of plant. Small annual plants become uprooted and disappear after being grazed. In browsing, taller plants such as trees and shrubs are little affected.

***(ii) Role of animals in pollination:***

A large number of plants depend on insects, birds and a number of animals for their pollination. These plants develop coloured flowers. The flowers possess scents, nectar, sap, edible pollens and many other characteristic structures for attracting insects towards them. Insects, birds and other pollinators visit the flowers in search of honey and edible pollens. Flowers in the families Rosaceae, Compositae, Leguminosae, Rutaceae, Umbelliferae, Euphorbiaceae, Cruciferae, Ranunculaceae are pollinated by insects.

Some plants are specialized in their pollination by particular type of animals, for example, *Rafflesia* is pollinated by elephants and birds, bilipped flowers of Salvia are pollinated by bees, entomophilous flowers of orchids, Ficus and Calotropis are pollinated characteristically by insects.

Besides insects, birds, bats and some other animals, man too is taking active part in pollinating artificially one plant with the pollen of some other plant species. The artificial pollination is being used by man for the production of high yielding and disease resistant plant varieties.

***(iii) Role of animals in the dispersal of fruits and seeds:***

Many animals, such as birds, bats, monkeys, act as important agents for disseminating the seeds, fruitsand spores and thus they play important role in the migration of plants. The seeds of many plants are very hard. Such seeds along with fleshy parts of fruits are swallowed by animals. While passing through the elementary canals of animals hard seeds are not affected by digestive juices.

When the animals leave faecal matter, the uninjured seeds present in it germinate. Passing of seeds through the digestive tracts sometimes facilitates their germination in certain cases. The seeds of tomato, tobacco, guava and many other plants are dispersed in this way.

The hairy, spiny, hooked and sticky fruits and seeds of some plants get entangled with the bodies of birds and other animals and with the clothes of man and are brought to distant places. When the animals clean their bodies at some places the seeds are dropped there. Seeds and fruits of *Xanthium, Andropogon, Plumbago, Aegle marmelos* are dispersed in this way. Ants are good agents for transporting oily seeds and small grains of cereals.

***(iv) Insects and Carnivorous plants:***

Semi-autotrophic insectivorous plants, as for example, pitcher plant, *Drosera*, *Aldrovanda*, *Dionaea*, bladderwort, etc., grow in the habitats which are deficient in nitrogenous compounds. These plants have some specialized organs and mechanisms for trapping and assimilating the preys.

***(v) Effects of human activities on vegetation:***

Man affects vegetation in the following ways:

(a) By cutting, felling and replanting the forest trees.

(b) Cultivation.

(c) Fire.

(d) Man also clears the vegetation for making houses, roads, etc.

***(vi) Myremecophily:***

Sometimes ants take their abode or shelter on some trees such as Mango, Litchi, Jamun, South American Acacia (*Acacia sphaerocephala*) and so on. These ants act as body guards of the plants against any disturbing agent. In lieu of this defence, the plants provide food and shelter to these ants. This phenomenon is known as myremecophily.

**2. Interaction among Plants Growing in a Community:**

Various plants in a community react with one another in several ways for:

(i) Water,

(ii) Essential minerals and organic compounds, and

(iii) Light and air.

The taller plants modify the habitat for the plants growing around and underneath them by casting shadow, protecting them from injuries by strong wind, by increasing the atmospheric humidity, andby determining the humus content of the soil.

The most interesting instances of interactions among plants growing in a community are as follows:

a. Action of lianas;
b. Effects of some epiphytes;
c. Effects of parasitic plants.

***a. Action of lianas:***

Lianas are woody vascular Discs plants growing on the ground, maintaining, more or less, autotrophic mode of life and growing upward taking support of some trees and other objects. The woody stems of these plants have well developed alternating vertical columns of secondary xylem and parenchymatous tissues which enable them to twist around the supporting objects.

***b. Effects of some epiphytes:***

The epiphytes grow on the leaves and stems of other plants. They are autotrophic and are dependent on other plants only for support. Epiphytes differ from parasites in not taking food from the hosts and also differ from lianas in not having any permanent connection with the soil. The examples of epiphytes may be found in the families Orchidaceae, Asclepiadaceae, Bromeliacease. Cactaceae, etc. *Dischidia*, *Tillandsia* are most common examples. Epiphytes are found in humid climates.

**The two main problems for these plants are:**

I. Maximum absorption of water from the atmosphere and from the bark surface of the supporting plant and
II. Maximum economy in the water consumption. These plants develop two types of roots, namely the aerial and clinging roots.

***c. Effects of parasitic plants:***

Parasitism has major impacts on host growth, allometry and reproduction, which lead to changes in competitive balances between host and non-host species and therefore affect community structure, vegetation zonation and population dynamics.

Parasites can affect ecological processes from the individual to the ecosystem level, influencing host behavior, population dynamics and interactions among species.

**3. Interaction between Plants and Microorganisms:**

Various kinds of bacteria, protozoa, algae, fungi, worms, nematodes and other soil microbes act as important agents which alter the physical and chemical properties of the soils and increase or decrease their fertility. These changes in the soil properties have great impact on the nature and growth of vegetation.

Very often soil microbes, such as nematodes, bacteria and fungi cause many diseases in the underground parts of plants. Viruses too cause several mosaic and other diseases in many plants, as for example, the curling of tomato leaves, mosaic patterns in papaya and lady's finger (bhindi), bean mosaic, tobacco mosaic, etc. Some microbes secrete growth stimulating substances in the soil which induce the growth of plants.

**Symbiotic influence:**

Some soil microbes live in close association with plants, both benefiting each other. In this association both the organisms are interdependent and they do not harm each other. This mutual relationship between two organisms is known as symbiosis and the interdependent organisms are called symbionts.

Many cases of symbiosis in plants are known. The nodulated roots of legumes contain nitrifying bacteria (*Rhizobium*) . These bacteria fix atmospheric nitrogen into nitrogenous compounds and benefit the legumes by supplying nitrogenous compounds in usable form.

Lichens also show symbiosis. These are synthetic plants in which algae and fungi live symbiotically. Generally, the algal component belongs to myxophyceae and fungal components are ascomycetous or sometimes basidiomycetous forms. In this association, algal component fixes the atmospheric nitrogen, prepares food and supplies nutrients to its fungal counterpart. Fungal component gives support to the algal component. It also saves algae from desiccation because of its sponginess and high water holding capacity.

**Mycorrhizal association:**

Sometimes fungi grow on the surface or inside the roots of higher plants. They are called mycorrhizae.

**Levels of organization of organisms in ecology:**

Ecosystems can be studied at small levels or at large levels. Levels of organization in ecology include the organism (species), population, community, ecosystem, and biosphere. The levels of organization are described below from the smallest to the largest –

- A **species** is a group of organisms that are genetically related and can breed to produce fertile young. Organisms are not members of the same species if their members cannot produce offspring that can also have children. The second word in the two-word name given to every organism is the species name. For example, in *Homo sapiens*, sapiens is the species name.
- A **population** is a group of organisms belonging to the same species that live in the same area and interact with one another.
- A **community** is all of the populations of different species that live in the same area and interact with one another. A community is composed of all of the biotic factors of an area.
- An **ecosystem** includes the living organisms (all the populations) in an area and the non-living aspects of the environment. An ecosystem is made of the biotic and abiotic factors in an area.
- The **biosphere** is the part of the planet with living organisms. The biosphere includes most of Earth, including part of the oceans and the atmosphere.
- An ecosystem is all the living things in an area interacting with all of the abiotic parts of the environment.

## 7. Habitat and Niche: concept of habitat and niche; niche width and overlap; fundamental and realized niche; competitive exclusion principle; extinction; resource partitioning; character displacement;

**speciation.**

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**Concept of habitat and niche:**

**Habitat:** Where organisms normally live. It comprises of all the biotic and abiotic factors in the area where the organism lives.

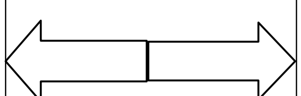
**Niche:** How organisms normally live. A niche is the *role* and *position* of a species in nature. It comprises of all the biotic and abiotic factors that the organism needs to survive, stay healthy and reproduce.

Obviously, the concepts of "niche" and "habitat" overlap, but "niche" focuses more on the organism's "role," while "habitat" focuses more on the nature of space/ place/ area that the organism occupies.

Ecologists use the term 'niche'to express the relationship of individuals or populations with all aspects of their environments, i.e., their ecological roles.Thus a 'niche' represents the range of conditions and resource qualities within which an individual or species can survive and reproduce.

**NICHE CONCEPT:** Hutchinson (1957) first defined the niche concept formally. According to him-

The activity range of any species can be described along every dimension of environment –

| **NICHE CONCEPT** | | |
|---|---|---|
| **PHYSICAL AND CHEMICAL** | | **BIOLOGICAL** |
| ▪ **Temperature**<br>▪ **Humidity**<br>▪ **Salinity**<br>▪ **Oxygen** |  | ▪ **Pests/ grazers**<br>▪ **Background/ landscapes against which the individual may escape detection by** |

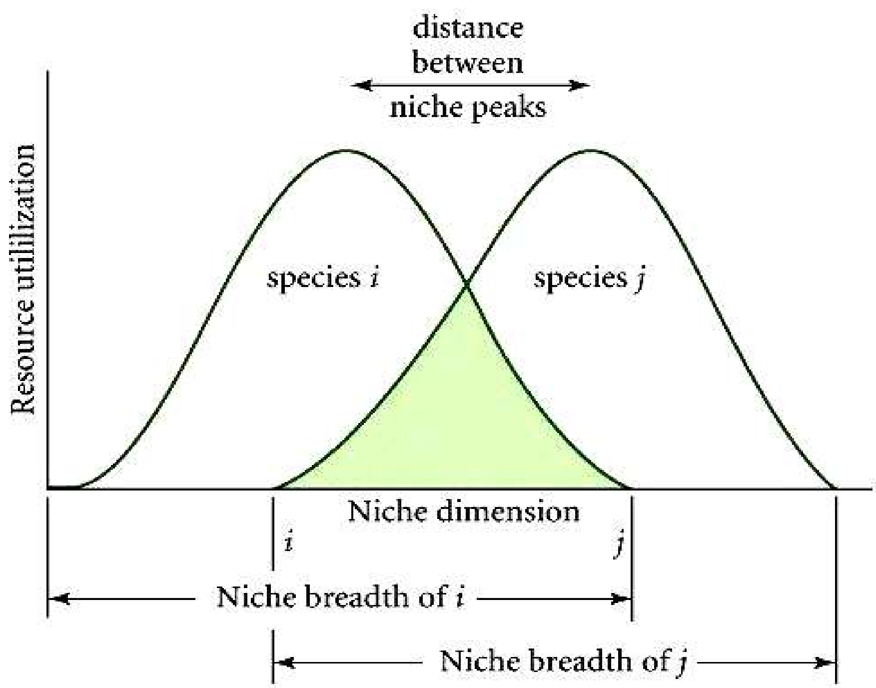
| | | |
|---|---|---|
| | | **pests/grazers** |

- Each of these dimensions may be thought of as a dimension in space.
- Suppose number of dimensions = n. Then niche is described in n-dimensional space.
- n-dimensional or multidimensional niche is an abstraction, also called ‘niche hypervolume’; multidimensional concepts can be dealt with mathematically or statistically, and their essence depicted graphically in 3 or less dimensions.
- The niche of each species occupies a part of the n - dimensional volume that represents total resource space, or niche space, available to the community.
- So total niche space of a community is the volume into which the niches of all th species of a community fit into.The number of species in a community thus depends upon the total amount of niche space & average size of each species’niche.
- Thus studies on niche deal with factors that determine both quantities because they are part of the processes that influence patterns of biodiversity.

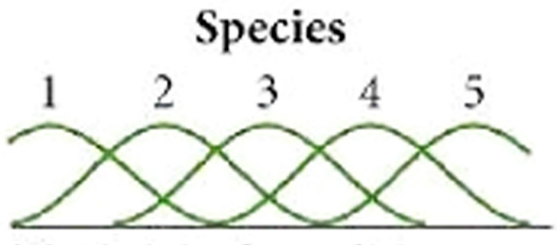
**Niche width and overlap:** It isdifficult to identify and measure all the n-dimensions of a species’niche.We characterize niche relationships by observing the patterns of resource utilization and microhabitat preferences.

**Niche breadth:** The extent of the variety of resources used or the range of conditions tolerated by the individuals in the population.

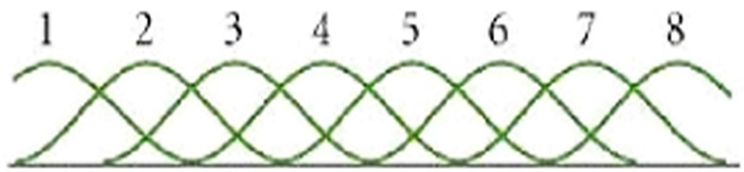
**Niche overlap:** The extent of similarity in resource utilization or tolerance



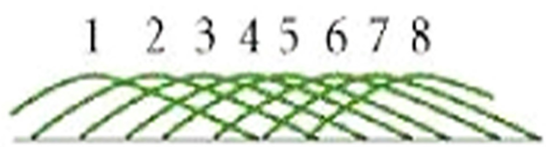
of conditions is called niche overlap. Resource utilization along a single niche axis can be altered to accommodate more species.



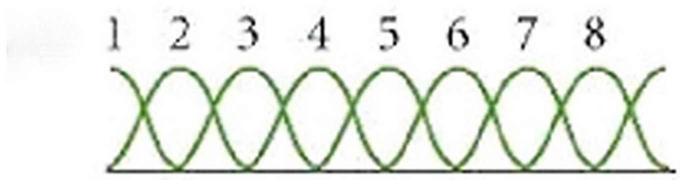

(a) Original condition




(b) Increased resource diversity




(c) Increased ecological overlap




(d) Increased specialisation

- Original community has a species richness of 5, with each species having same nichebreadth.

- Additional resource types are added (shown with extended axis).
- The niche overlap among species increases.
- The niche breadth of the species decreases. Both 'c'& 'd'are forms of 'species packing'- an increase in 'S' without change in resource diversity. Species packing resultsin an overall reduction in productivity of the species, as each has.

**Fundamental and realized niche:Ecological Niches**

The niche of a species (or an individual) refers to the ways in which it interacts with its environment, so niches are closely related to environmental tolerance curves, but niches can have behavioral dimensions (e.g method of locomotion - running, swimming, flying) as well environmental ones (e.g temperature limits).

Fundamental niche is the entire set of conditions under which an animal (population, species) can survive and reproduce itself. The niche of any organism is the role that it fills within an *ecosystem* as a response to the amount and distribution of resources, the competition present, and the way that the organism influences those same factors.

A fundamental *niche* is the full range of environmental conditions that a viable population of species can occupy and use, without any other *limiting factors* present which could constrain the population.

The fundamental niche is the potential niche that could be filled and is affected by the *life history traits* of each species and each individual organism – their dispersal ability, their tolerance to different environmental conditions, and the way in which they interact with other species.

**Examples of Fundamental Niche Sparrows in a Forest**

Within a forest, a population of sparrows feeds on berries that grow abundantly on bushes. The fundamental niche of the sparrows is the area where there are berries, and covers the whole of each bush as well as the forest floor, where many of the berries have fallen to the ground. However, mice, which live on the forest floor, also like to eat berries, and are quick to collect them once they have fallen. The presence of the mice causes *interspecific competition* and means that there are fewer or no berries to eat on the forest floor. The fundamental niche of the sparrows cannot be met, so they fill the *realized niche*, which is the area on the bush branches only.

The *interspecific competition* between the sparrows and the mice affects the *geographic range* of the populations; however, the individuals within the populations are also affected by *intraspecific competition*. Certain bushes within the forest may receive more light, nutrition or water than other bushes, and therefore may yield larger and more nutritious berries. Sparrows that are larger or more aggressive could claim territorial ownership over the best bushes and the actual niche of the smaller sparrows (fundamentally, covering all of the bushes in the absence of other sparrows) would be restricted to bushes with smaller, less nutritious berries.

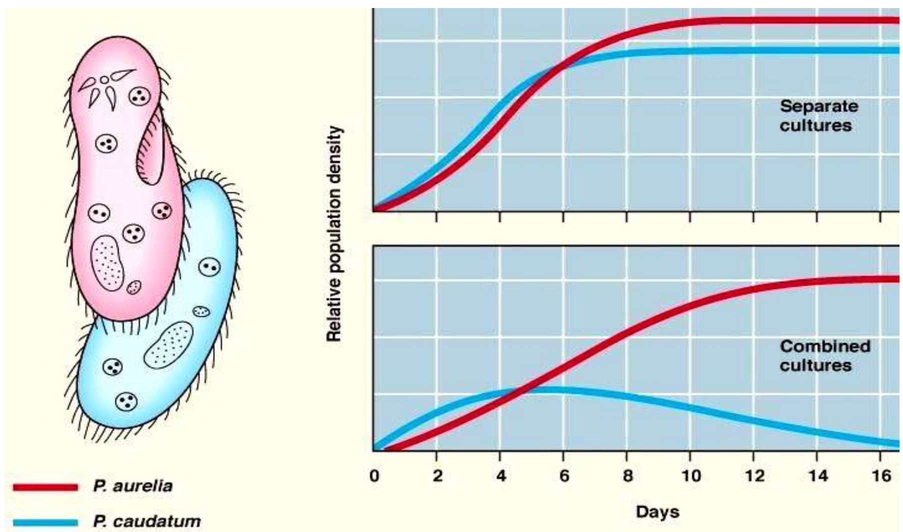
Finally, the fundamental niche of each sparrow includes access to all the berries on all the branches on a bush; the presence of kestrels in the forest, however, introduces a *limiting factor* of *predation*. Sparrows avoid the berries on the ends of branches within a bush because these areas are exposed, meaning they are more likely to be seen by kestrels.

Realized niche is the set of conditions actually used by given animal (pop, species), after interactions with other species (predation and especially competition) have been taken into account. Because of interspecific interactions, the realized niche of a species may be considerably smaller than its fundamental niche.

Sometimes FN and RN are termed precompetitive and postcompetitive niches, reflecting a traditional focus on interspecific competition's effect on niches.

**Competitive Exclusion Principle:**

In ecology, the competitive exclusion principle, sometimes referred to as Gause's law, is a proposition named for Georgy Gause that two species competing for the same limiting resource cannot coexist at constant population values. When one species has even the slightest advantage over another, the one with the advantage will dominate in the long term. This leads either to the extinction of the weaker competitor or to an evolutionary or behavioral shift toward a different ecological niceh. The principle has been paraphrased in the maxim "complete competitors cannot coexist"




*Paramecium aurelia* and *Paramecium caudatum* grow well individually, but when they compete for the same resources, *P. aurelia* outcompetes *P. caudatum*.

Based on field observations, Joseph Grinnell formulated the principle of competitive exclusion in 1904: "Two species of approximately the same food habits are not likely to remain long evenly balanced in numbers in the same region. One will crowd out the other". Russian ecologist Georgy Gause formulated the law of competitive exclusion based on laboratory competition experiments using two species of *Paramecium*, *P. aurelia* and *P. caudatum*. The conditions were to add fresh water every day and input a constant flow of food. Although *P. caudatum* initially dominated, *P. aurelia* recoveredand subsequently drove

*P. caudatum* extinct via exploitative resource competition. However, Gause was able to let the

*P. caudatum* survive by differing the environmental parameters (food, water). Thus, Gause's law is valid only if the ecological factors are constant.

Gause also studied competition between two species of yeast, finding that *Saccharomyces cerevisiae* consistently outcompeted *chizosa ccharSomyces* by producing a higher concentration of ethyl alcohol.

**Extinction:**

Extinction is an important part of the process of evolution of biodiversity and does not occur at a constant pace. It is the complete disappearance of a species from Earth. Thus, extinction is the final and irreversible event of species loss. In contrast, extirpation is the local or regional disappearance of aspecies from only a part of its range.

There have been at least five periods when there was a sudden increase in the rate of extinction – to at least double – affecting many different types of plants and animals.

**Major Five Extinction events include:**

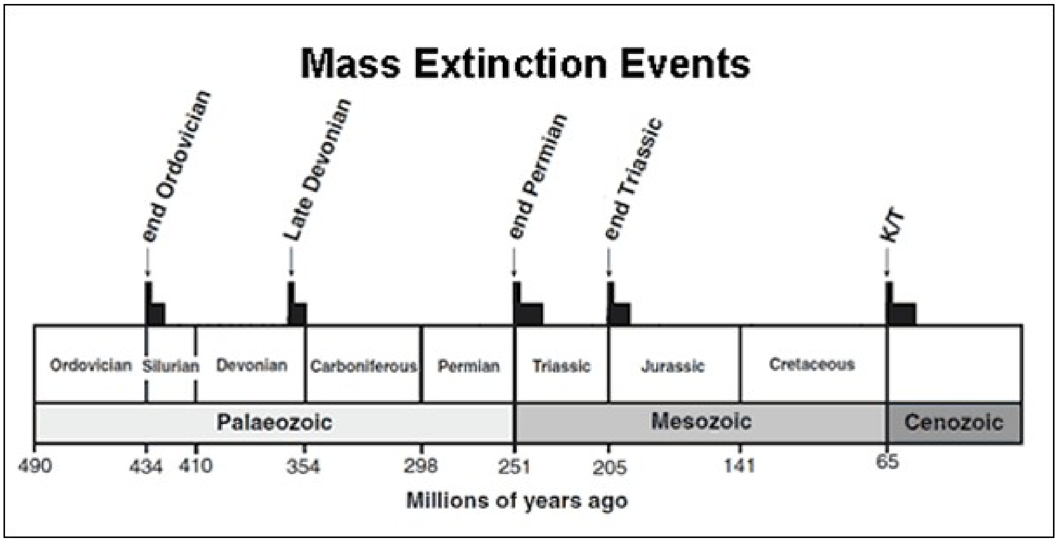
**Cretaceous-Tertiary Extinction Event** (75% of all species including the dinosaurs) about 75 millionyears ago.

**Triassic–Jurassic Extinction Event** (60% of all species including most Achosaurs, Therapsids, andlarge Amphibians) about 205 million years ago.

**Permian–Triassic Extinction Event** (96% of Aquatic Species including most of the sessile species; and 70% of land species including most Synapsids) 251 million years ago.

**Late Devonian Extinction Event** (70% of all species including most Brachiopods and Trilobites) 360million years ago.

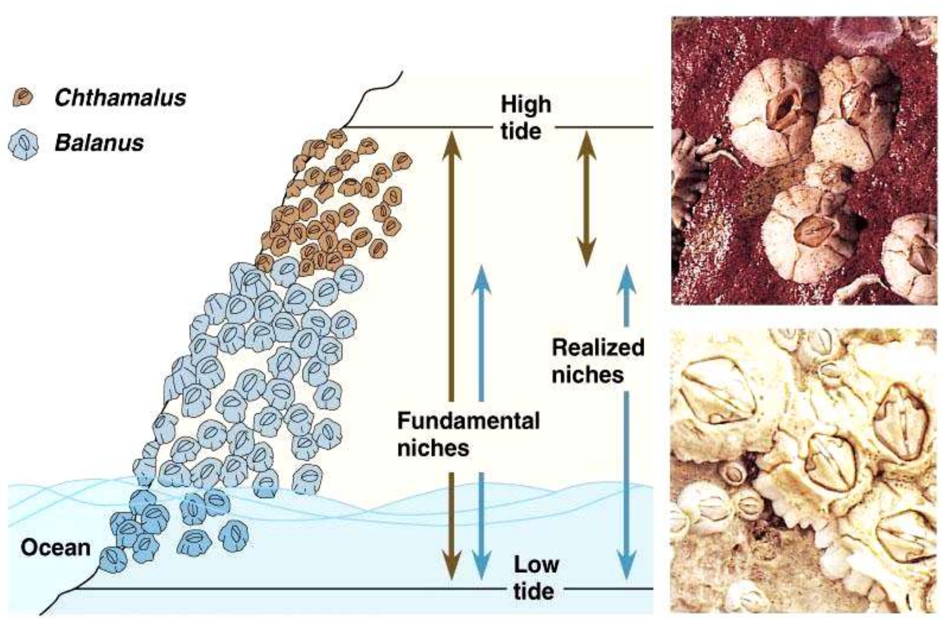
**Ordovician–Silurian Extinction Event** (80% of all species, mostly brachiopods, bivalves,echinoderms, bryozoans, and corals) 450 million years ago.



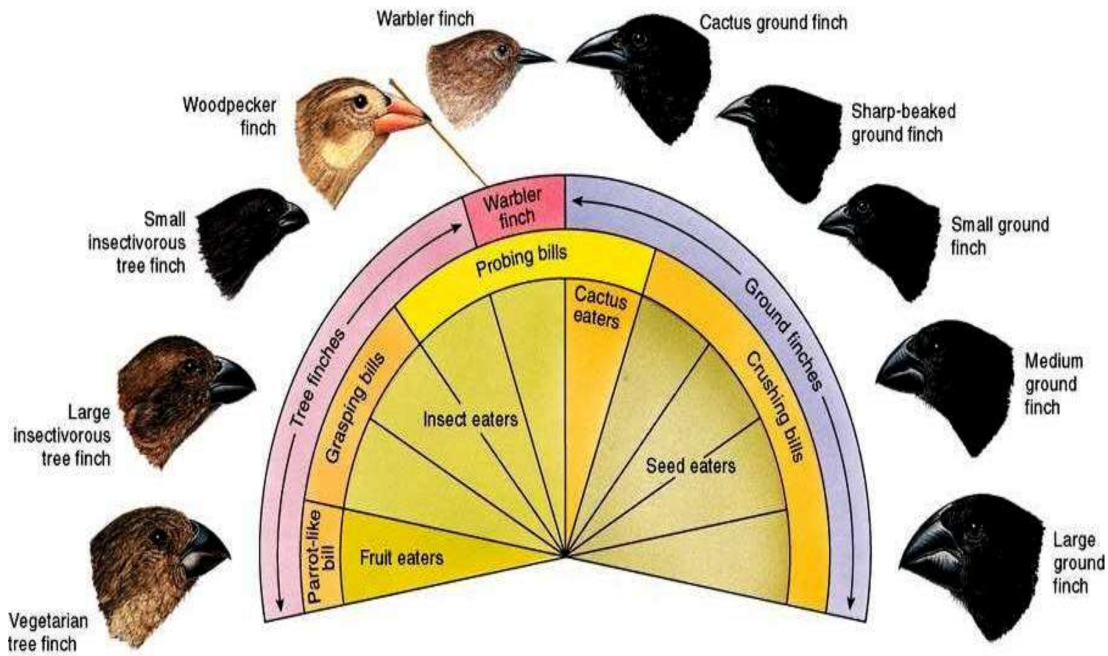

**Resource Partitioning:**

Natural selection favours changes among competitors to reduce the competition between them. Each species can avoid competition by using different resources than competitors this reduces niche overlap.

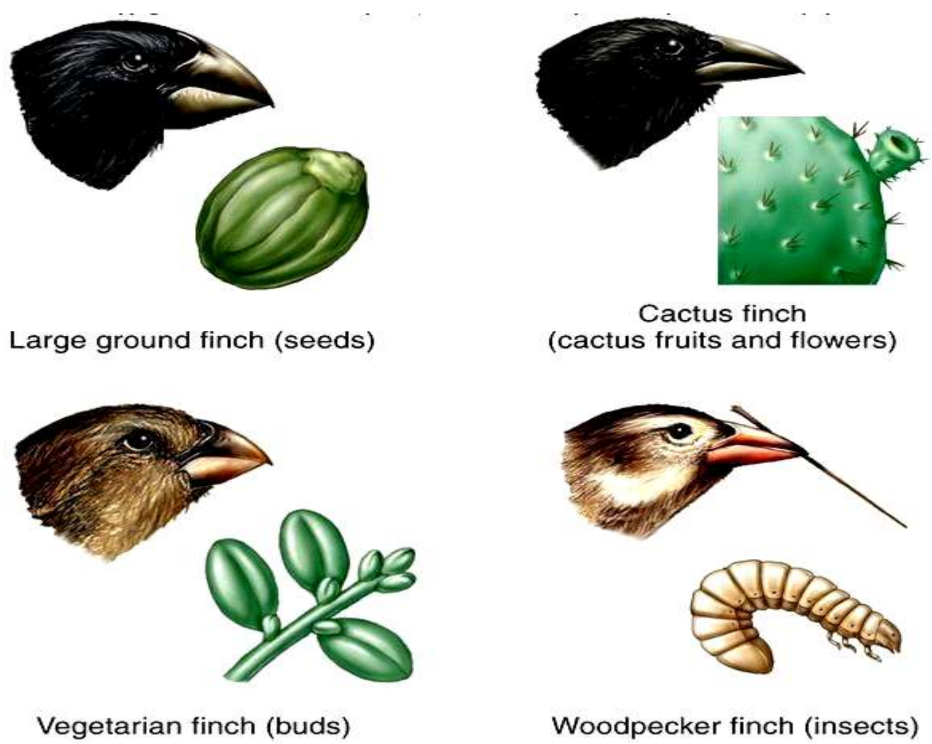
**EXAMPLE 1:** Connel (1961) did a classic experiment on barnacles, he showed that *Balanus* and *Chthamalus* can coexist because they differ in two traits: growth rate and vulnerability to desiccation. *Balanus*'s growth is rapid, which allows it to crush the slower-growing *Chthamalus. Balanus,* however, dies close to shore because it gets too dry during low tide. *Chthamalus* however, tolerates dry conditions. So, even though *Balanus* is a better competitor for space, the barnacles coexist because *Chthamalus* can survive in areas that *Balanus* cannot survive.



EXAMPLE 2: **Darwin's finches** are a closely related group of distinct species.All the birds are similar to each other except for the shape of their bills.Genetic differences account for the physical differencesin the beaks.



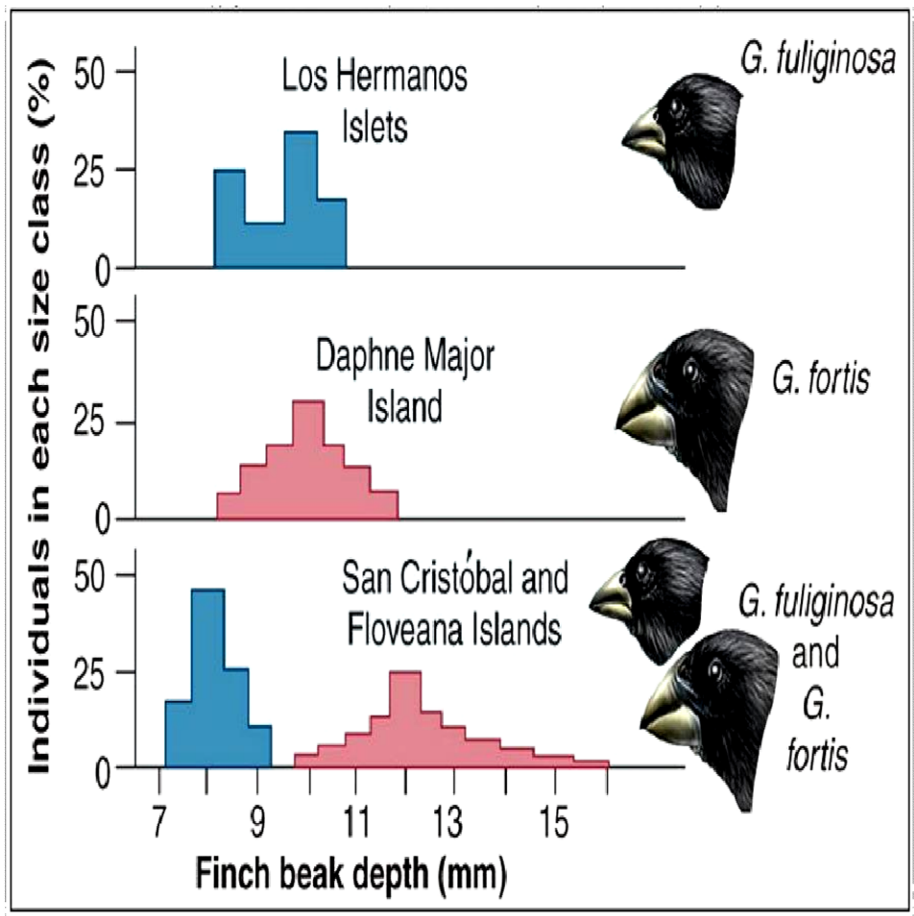

Darwin observed that, although all the finches shared a common ancestor, their beak sizes hadevolved to suit their food. Darwin termed this "**descent with modification**."



**Character Displacement:**

Similar species evolve in such a way so as to become different from each other by enhancing their initial minor differences. Thus natural selection can result in morphological changes inspecies that reduce competitive effects.

Character displacement occurs as changes in competing species to reduce niche overlap species that live together show more distinctiveness than do species living separately.




**Speciation:**

Speciation is the formation of one or more new species from an existing species.

A species is a collection of demes. The deme is a group of populations with common gene pool.

**Types of Speciation:**

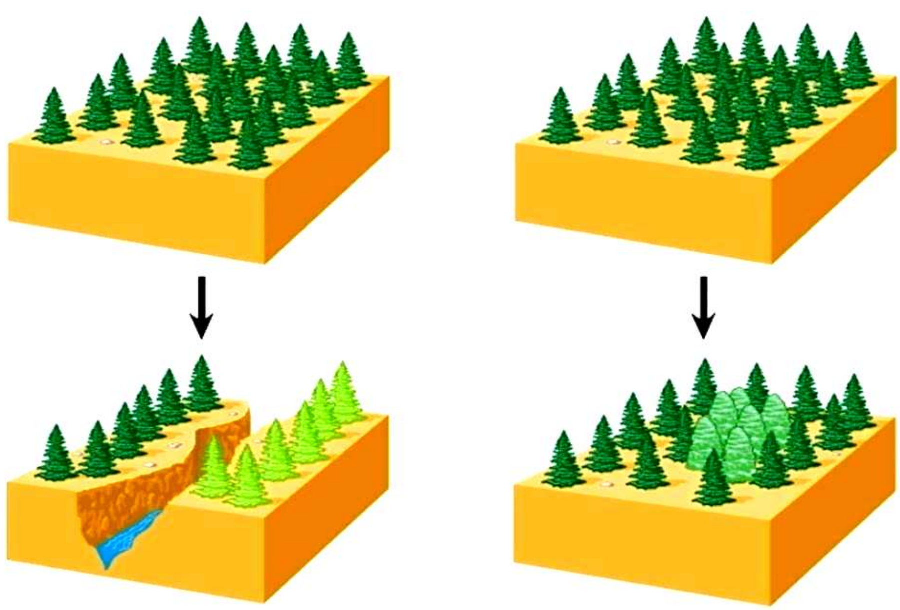
Speciation is of following types.

**1. Allopatric Speciation (alios— other, patria— native land):**

In this type of species formation, a part of the population becomes geographically isolated from the main popula•tion. The population becomes entirely separated and finally constitutes a new species. Thus geographic isolation brings about allopatric speciation. An important example of this type of speciation is formation of Darwin's finches that formed separate species in the Galapagos Islands.

**2. Peripatric Speciation:**

In peripatric speciation, a subform of allopatric speciation, new species are formed in isolated, smaller peripheral populations that are prevented from exchanging genes with the main population. It is related to the concept of a founder effect, since small populations often undergo bottlenecks. Genetic drift is often proposed to play a significant role in peripatric speciation. Case studies include Mayr's investigation of bird fauna; the Australian bird Petroica multicolor; and reproductive isolation in populations of *Drosophila* subject to population bottlenecking.



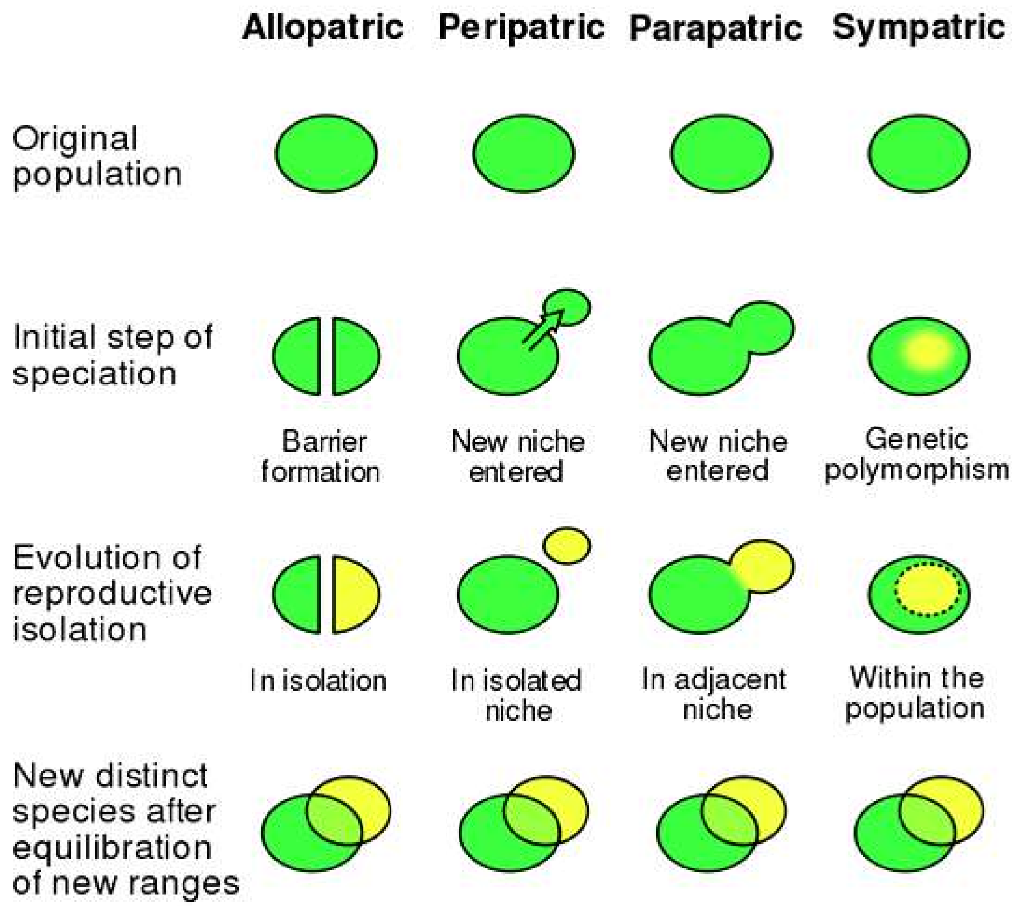
(a) Allopatric speciation (b) Sympatric speciation

**3. Sympatric Speciation (sym— together, patria— native land):**

In this type of species formation, a small segment of the original population becomes isolated reproductively. As the isolating mechanism comes into force, a new subspecies emerges. In due course of time a new species is formed. Thus sympatric speciation is the formation of species within a single population without geographical isolation. The reproductive isolation brings about sympatric speciation.

**4. Parapatric Speciation:**

It separates adjacent population. Parapatric speciation takes place when a population of a species enters a new niche or habitat. It occurs only at the edge of the parent species range. Although there is no physical barrier between these populations, yet the occupancy of a new niche results as a barrier to gene flow between the population of new niche. Two species are produced due to reproductive isolation from single one. Such type of speciation is found in flightless grasshoppers, smails and annual plants. Many competitors have populations that occur sympatrically or allopatrically for existence.


Allopatric
Peripatric
Parapatric
Sympatric
Original population
Initial step of speciation
Barrier formation
New niche entered
New niche entered
Genetic polymorphism
Evolution of reproductive isolation
In isolation
In isolated niche
In adjacent niche
Within the population
New distinct species after equilibration of new ranges

## 8. Population Ecology: characteristics of population; population growth curves, population regulation, life history strategies (r and K selection); metapopulation, habitat fragmentation, demes, source-sink model; population interactions (competition, parasitism, mutualism).

**Population Ecology:**

**Population ecology** is a sub-field of ecology that deals with the dynamics of species populations and how these populations interact with the environment. It is the study of how the population sizes of species change over time and space. The term population ecology is often used interchangeably with population biology or population dynamics.

| Term | Definition |
|---|---|
| **Species population** | All individuals of a species. |
| **Metapopulation** | A set of spatially disjunct populations, among which there is someimmigration. |
| **Population** | A group of conspecific individuals that is demographically, geneticallyor spatially disjunct from other groups of individuals. |
| **Deme** | A group of individuals more genetically similar to each other than to other individuals, usually with some degree of spatial isolation as well. |
| **Local population** | A group of individuals within an investigator-delimited area smaller than the geographic range of the species and often within a population (as defined above). A local population could be a disjunct population as well. |

| | |
|---|---|
| **Subpopulation** | An arbitrary spatially delimited subset of individuals from within apopulation (as defined above). |

It is the analyses of population characteristics especially the associated dynamics, by exploring how biotic and abiotic factors influence the distribution, size and age of a population.

The studies pertaining to population ecology include -

- Intra-specific competition
- Inter-specific interactions
- Population growth
- Population regulation
- Life-history strategies

**Characteristics of population:**

Populations have developed separately but the life forms that contribute to populations have much in common in terms of 'population structures' and 'population processes'.

The related parameters of 'structures' and 'processes' define the characteristics of populations.

- Boundary
- Size
- Density
- Dispersion
- Survivorship Curves
- Genetic diversity
- Births & Deaths
- Immigration & Emigration

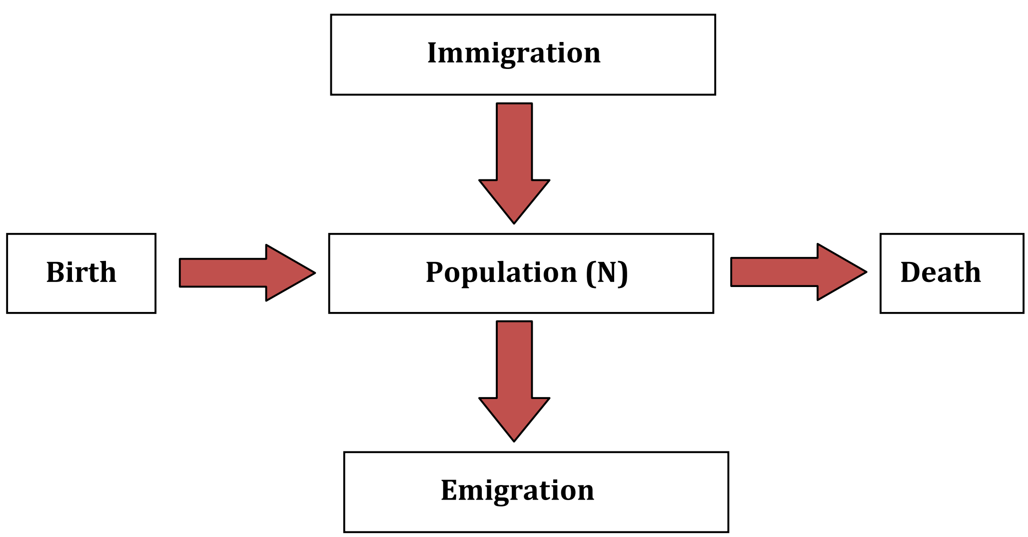
**Population structure:**

- **Boundary**: The boundary in the form of an island, zone, state, country, is defined for apopulation.
- **Size**: Number of individuals in the population.
- **Density**: Number of individuals per unit area.
- **Dispersion**: How individuals are spaced within the population using measures likeinterspersion/ juxtaposition.
- **Life tables**: Proportion of individuals in different age.
- **Survivorship curves:** Classes.
- **Genetic diversity:** Relationships between genetic diversity and population size.

**Population processes:**

- **Births, Deaths**
- **Immigration and Emigration**

## Parameters that effect size or density of a population



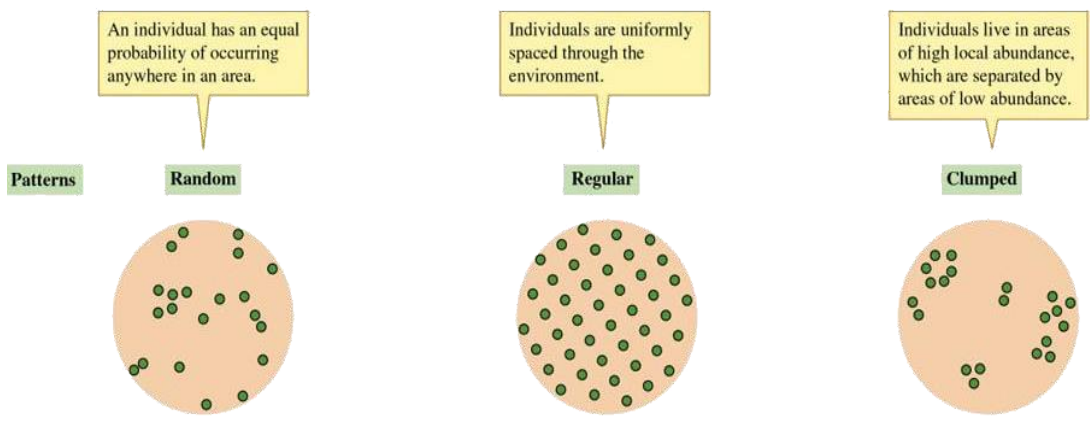
**Population dynamics:**

These are attributes of the populations and not of the individual plants or animals, just like population characteristics, since, populations have attributes that individuals do not have and are usually more than just the sum of properties of individuals.

1. **Changes in numbers** – *Reflects on whether a particular population of plants is increasing ordecreasing.*
2. **Spatial dispersion** – *Reflects on how plants in the population are arranged spatially.*
3. **Genetic composition –** *Reflects on the genetic variability within a population.*

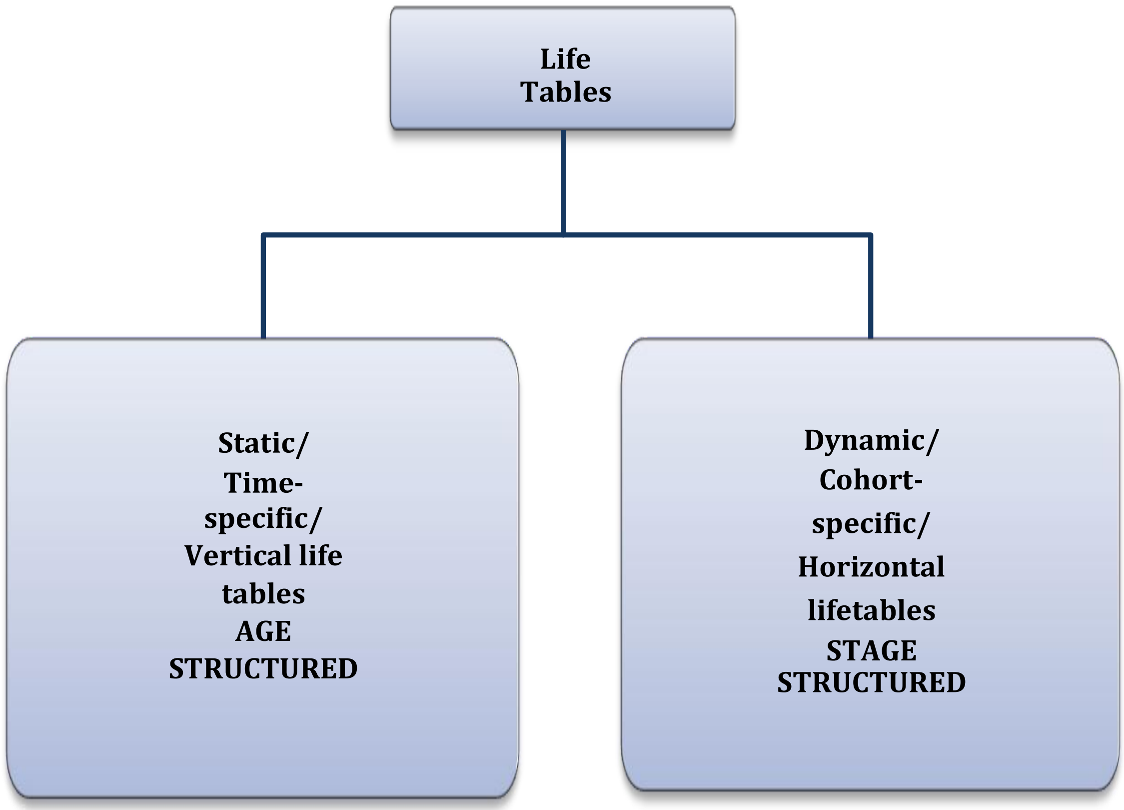
**Population structure: Dispersion**

- **i.** Random
- **ii.** Regular
- **iii.** Clumped




**Population structure: Life tables**

Life table is a summary by age of the survivorship and fecundity of individuals in a population**.**




**Population structure: Life tables**

- **Elements of life tables:**

1. Age-structure of the population

   *(Number of different age-classes and the number of individuals in each age class at aparticular time)*

2. Fecundity of the population

   *(Rate at which offsprings are produced in a population)*

**Life table variables:**

Life tables provide a schedule of age-specific mortality and survival. The variables needed forconstructing life tables.

1. Survivability of newborn individuals of the population to a specific age;
2. Fecundity of individuals of the population at a specific age;

3. Proportion of individuals of the population dying at a specific age;
4. Proportion of individuals of the population surviving to a specific age;
5. Expectation of further life of individuals of the population to a specific age.

**Utility of life tables in plant population studies:**

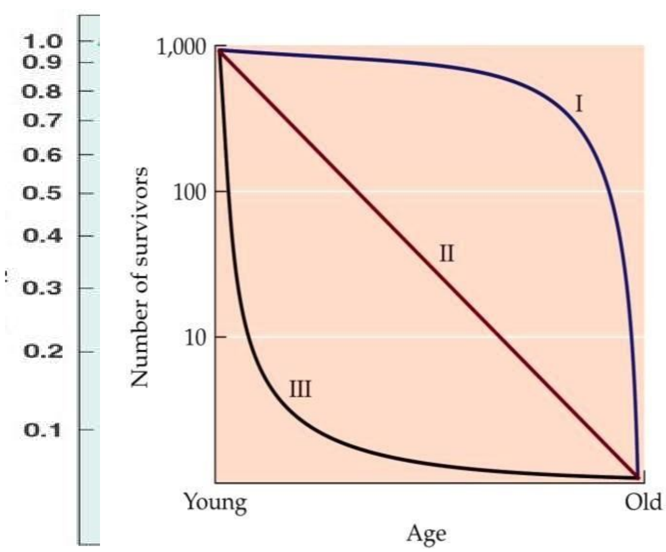
1. Seedling mortality and survival studies;
2. Population dynamics of plants;
3. Life cycles and phenological studies.

**Types of life tables:**

Age-structured life tables are justifiable only if individuals of a population can be classified meaningfully by age alone. In plants, specially in perennials, the fate of an individual is not so much dependent on its absolute age as on its size and stage of growth. In such cases, **stage- structured life tables** are useful means of defining population dynamics.

**Survivorship Curves:**

The time interval is on the horizontal axis and survivorship ($l_x$) is on the vertical axis. Survivorship Curves fall into three general idealized types. The generalized survivorship curves are idealized models to which a species can be compared. Many Survivorship Curves show components of these 3 generalized types at different times in their life histories.



## Types of survivorship curves

- Type I = Individuals tend to live out their physiological life span, with high survival rate throughout their life span followed by heavy mortality at the end. Strongly convex curve (humans, other mammals, some plants).
- Type II = Survival rate does not vary with age. Straight line (birds, rodents, reptiles, small perennial plants).
- Type III = Mortality rate extremely high in early life. Concave curve (oysters, fish, most invertebrates & tree species).

**Population structure:**

**Genetic diversity**

- Small populations support less genetic variations;
- Reduced genetic diversity influence the ability of a population to adapt itself to new diseases, new predators or changes in the physical environment or climate change adaptations;
- Two mechanisms operating in a population can lead to such situations, *i.e.*, reduced geneticdiversity.
- Genetic drift
- Inbreeding

**Genetic drift:** Along with natural selection, mutation, & migration is one of the basic mechanisms of evolution.

- A random process occurring in a population, leading to reduction in the genetic diversity within the population.
- This reduction in the frequency of alleles within the gene pool is called genetic drift.
- It occurs in all populations and represents a mechanism of evolution, although the rate of genetic drift is faster in small, isolated populations.

- On a time scale, some genes become homozygous for one allele in a population and if the gene involved in such a situation happens to be maladaptive, the small population may become extinct.

**Population Process:**

**Growth**

- How the number of individuals in a population increases or decreases with time.
- Controlled by the processes of births & deaths and rates of immigration & emigration.
- Populations in which immigration & emigration occur & have significant effect on populationgrowth are called **open populations**.
- Populations in which immigration & emigration does not occur or does not have significanteffect on population growth are called **closed populations.**

**Population Models:**

| | Discrete reproduction | Continuous reproduction |
|---|---|---|
| **Non overlapping generations** | **Annual plants** | **Bacteria** |
| **Overlapping generations** | **Higher plants** | **Human beings** |

**Population process dynamics:**

Change in population size (ΔN) is defined by the following equation:

$$\Delta N = B + I - D - E$$

$$N_{t+1} = N_t + \Delta N$$

or

$$N_{t+1} = N_t + (B + I) - (D + E)$$

$N_t$ is the population size at time $t$

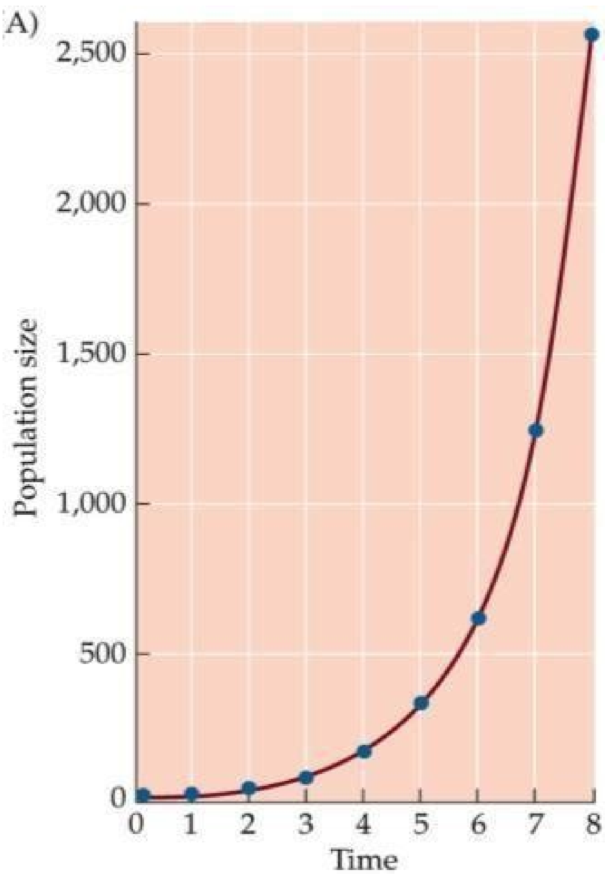
$N_{t+1}$ is the population size one time period later, at time *t+1* *B* is the number of new individuals born between *t* and *t+1* *D* is the number of individuals which die between *t* and *t+1*

*I* & *E* are the numbers of immigrants & emigrants during the same period.

**Exponential population growth:**

In the case of J-shaped growth form, the population grows exponentially, and after attaining the peak value, the population may abruptly crash. This increase in population is continued till large amount of food materials exist in the habitat.

After some time, due to increase in population size, food supply in the habitat becomes




*ponential Population Growth*

*'/dt = rN*

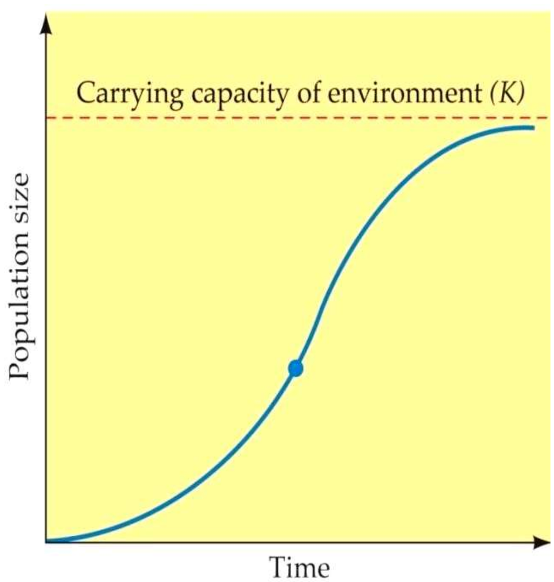
*r Nt =* $N_0e^{rt}$

limited which ultimately results in decrease in population size. For example, many insect populations show explosiveincrease in numbers during the rainy season, followed by their disappearance at the end of the season.He also gave the estimate of an elephant population that after 500 years there would be nearly 16 thousand x elephants alive, who have descended from the first pair.

**Logistic population growth**

When a few organisms are introduced in an area, the population increase is very slow in the beginning, i.e., positive acceleration phase or lag phase, in the middle phase, the population increase becomes very rapid, i.e., logarithmic phase, and finally in the last phase the population increase is slowed down, i.e., negative acceleration phase, until an equilibrium is attained around which the population size fluctuates according to variability of environment.

The level beyond which no major increase can occur is referred to as saturation level or carrying capacity (K). In the last phase the new organisms are almost equal to the number of dying individuals and thus there is no more increase in population size.




The **logistic model of population growth** incorporates the concept of carrying capacity (K).

$$\frac{\Delta N}{\Delta t} = r\left(\frac{K-N}{K}\right)N$$

(K – N) = # of individuals a population can accommodate

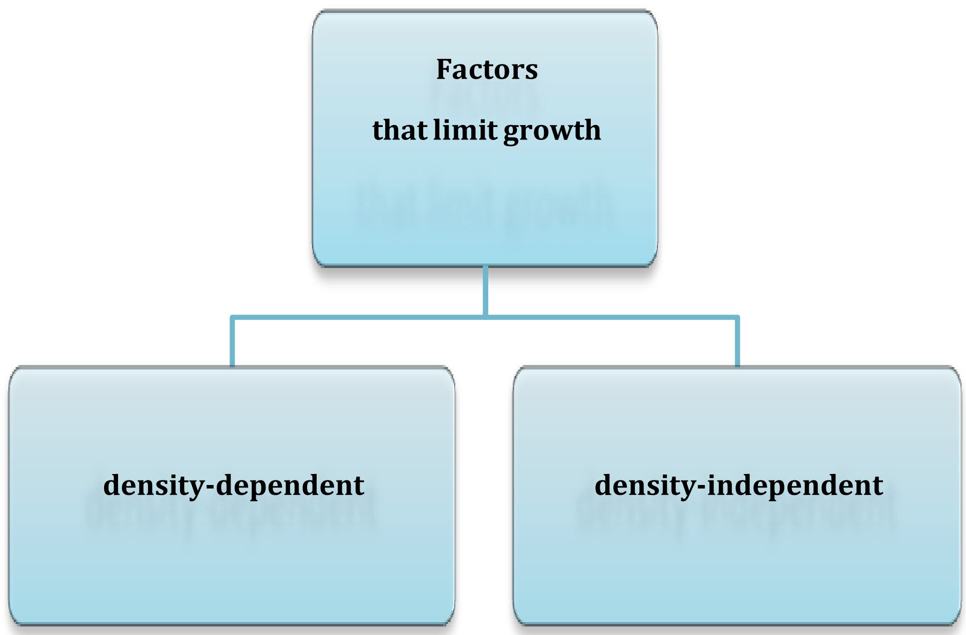
**Logistic Growth Rate (S-shaped curve)**

Rate of population growth slows as the population size approaches carrying capacity (K), leveling to a constant level.

**Population regulation**

Logistic equations have been successful in describing growth of populations in the laboratoryand natural environments.

It suggests that factors that limit growth exert stronger effects on mortality and fecundity as apopulation grows.




- **Density-dependent Factors:** Factors whose effect increase with crowding
  1. Limitations in food supplies
  2. Limitations in space occupancy
  3. Effect of predators/ grazers
  4. Effect of parasites/ pests
  5. Effect of diseases/ epidemics

These effects are felt more strongly when the population is more crowded than in sparsepopulations and are responsible for bringing populations under control.

- **Density-independent Factors:** Factors that are unaffected by population size

1. Temperature
2. Precipitation
3. Catastrophic events
4. Extreme climate events

These factors may influence the exponential growth rate of a population, but they do not regulate the size that the population will attain in the environment

**Density vagueness:**

- **Demographic stochasticity**: variations in birth & death and
- **Environmental stochasticity**: variations in environmental conditions may obscure the effects of density dependence, giving rise to a situation called '**density vagueness**'. As a result of this obscurity the concept of population equilibrium raises doubt.

So it is likely that a combined effect/ interaction of both factors (density-dependent & density-independent) regulate population levels and can cause complex population dynamics.

**Life history strategies:**

- r & K selection strategy
- Grime's Triangular Model

Dobzhansky (1950) proposed that natural selection in the tropics operates in a fundamentally different way than it does in temperate zones. He argued that much of the mortality in the temperate zones is relatively independent of the genotype of the organism concerned & has little to do with the size of the population. (eg. mass winter kills of many fish and bird species). But in the tropics where environment is more constant, most mortality is more directed generally favouring individuals with better competitive abilities.

Accordingly it was derived that in the temperate zones selection often favours high fecundity and rapid development, whereas in the tropics lower fecundity and slower development could increase competitive ability.

One of the ways of classifying **environments** or **species habitats** and also

**evolutionary strategies** relates to their **variability in time**

1. **those that are short-lived**
2. ***those that are long-lived***

The ecologists Robert Mac Arthur & E. O. Wilson used this dichotomy and Dobzhansky's inference to develop the concept of ***r*- and *K*- selection,** though these are clearly not found to be restricted to tropical or temperate zones as was thought earlier.

The initials ***r*** and ***K*** are derived from the logistic equation for describing actual rate ofgrowth of populations.

***K*** refers to the carrying capacity

***r*** refers to the maximal intrinsic rate of natural increase [$r_{max}$]

$$\frac{\Delta N}{\Delta t} = r\left(\frac{K-N}{K}\right)N$$

The theory of ***r*- and *K*- selection** predicts that species adapted to these two different environments will differ in life history traits such as size, fecundity, age at first reproduction, no. of reproductive events and total life span. These parameters taken together reflect upon the **evolutionary strategies** of populations.

**Life history strategies as evolutionary strategies:**

Different organisms have evolved different sets of traits related to population dynamics. Traits that affect an organism's schedule of reproduction and survival make up its **life history.**

**Semelparous:**

- Reproduction occurs once **(semelparity)**
- It occurs after one season
- Death occurs after reproduction
- Many small seeds are produced
- Favored in unstable environment

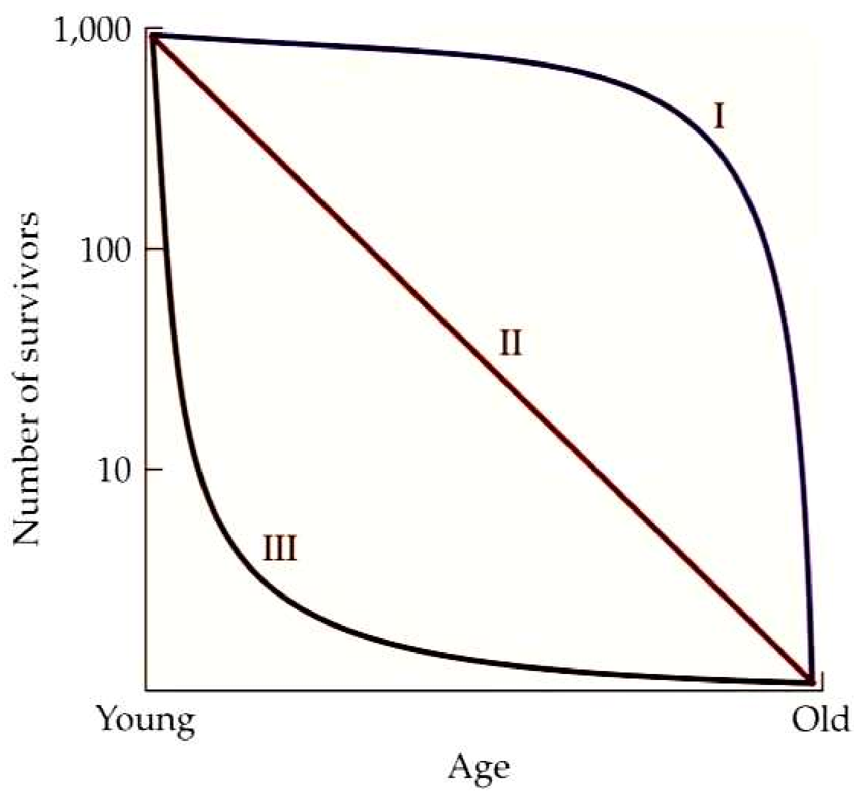
**Iteroparous**

- Reproduction occurs more than once **(iteroparity)**
- It occurs after many seasons
- Larger seeds are produced (few well-provisioned seeds have higher survival rates)
- Favored in stable environments

**Survivorship curves as indicators of evolutionary strategies:**

The survivorship curves indicate the evolutionary strategies of species & how nos. in population are maintained

- Individuals in populations with curves like 'I' & 'II' usually have few offsprings. These offsprings are well cared for so that their chance of survival is high. (eg. birds, rodents, humans, some plants, etc.)
- Individuals in populations with curves like 'III' usually have large number of offsprings, most of which die before they reach maturity. (eg. many plant species, fungi, fish, amphibians, etc.)



**Evolutionary strategies of populations**

*r*- & *K*-selection as an evolutionary strategy:

Another way of classifying evolutionary strategies was suggested by MacArthur & Wilson (1967).

They applied the terms ***r-selected*** and ***K-selected*** to populations classifying themaccordingly as different ecological strategies that populations adopt.

- An *r*-selected population is one in which the maximum rate of increase (r) is important.

  A *K*-selected population is associated with a steady carrying capacity (K).

- An *r*-selected population can take advantage of a favorable situation by having the abilityto increase population size rapidly.

  A *K*-selected population is less capable of taking advantage of such opportunities for increasing population size.

- An *r*-selected population can produce many offsprings, which under normal circumstances die before reaching maturity but may survive if circumstances change. Thus being associated with Type III survivorship curve.

  A *K*-selected population produces few, well cared offsprings, and are more stable and unlikely to suffer high mortality rates. Thus being associated with Type I and Type II survivorship curves.

**Some correlates of r- & K-selection - Pianka (1970):**

| | *r*-selection | *K*-selection |
|---|---|---|
| Climate | Variable and unpredictable; uncertain | Fairly constant or predictable; more certain |
| Mortality | Often catastrophic, nondirected, density independent | More directed, density dependent |
| Survivorship | Often Type III | Usually Types I and II |
| Population size | Variable in time, nonequilibrium; usually well below carrying capacity of environment; unsaturated communities or portions thereof; ecologic vacuums; recolonization each year | Fairly constant in time, equilibrium; at or near carrying capacity of the environment; saturated communities; no recolonization necessary |
| Intra- and interspecific competition | Variable, often lax | Usually keen |
| Selection favors | 1. Rapid development<br>2. High maximal rate of increase, $r_{max}$<br>3. Early reproduction<br>4. Small body size<br>5. Single reproduction<br>6. Many small offspring | 1. Slower development<br>2. Greater competitive ability<br>3. Delayed reproduction<br>4. Larger body size<br>5. Repeated reproduction<br>6. Fewer, larger progeny |
| Length of life | Short, usually less than a year | Longer, usually more than a year |
| Leads to | Productivity | Efficiency |
| Stage in succession | Early | Late, climax |

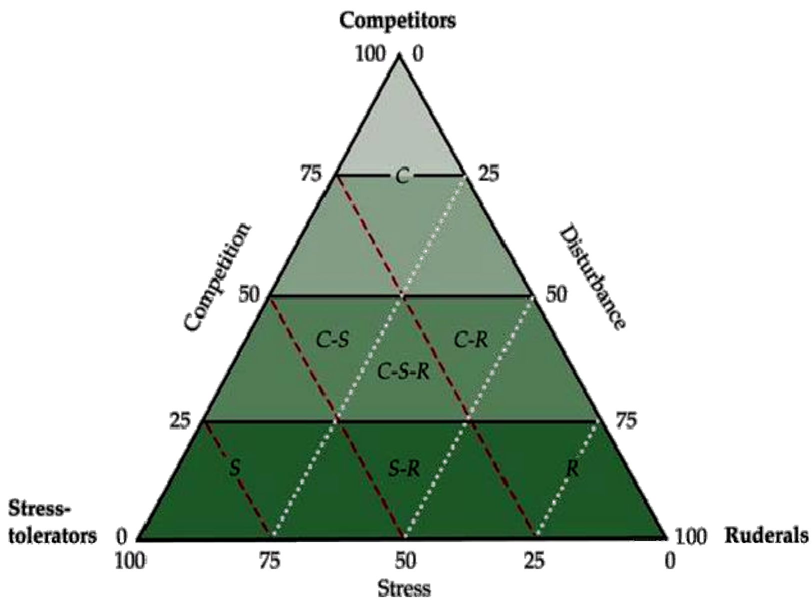
## The continuum concept of *r*- & *K*-selection

- The two classes *r*- & *K*-selection are actually the extreme ends of a continuum of adopted strategies of organisms (Pianka, 1970).
- Each end is associated with a whole group of characteristics of life which fit together into aparticular evolutionary strategy.*r*- & *K*-selection are also known as density- independent and density-dependent selection.
- No organism is completely *r*-selected or completely *K*-selected, rather all must reach some compromise between these two extremes. An organism can be considered as an "*r*-strategist" or a "*K*-strategist" only relative to some other organism; thus statements about *r* and *K* selection are invariably comparative. Eg. Cats and dogs are *r*-selected compared to humans, but *K*-selected compared

to mice and rats. Mice and rats, in turn, are *K*-selected compared to most insects.

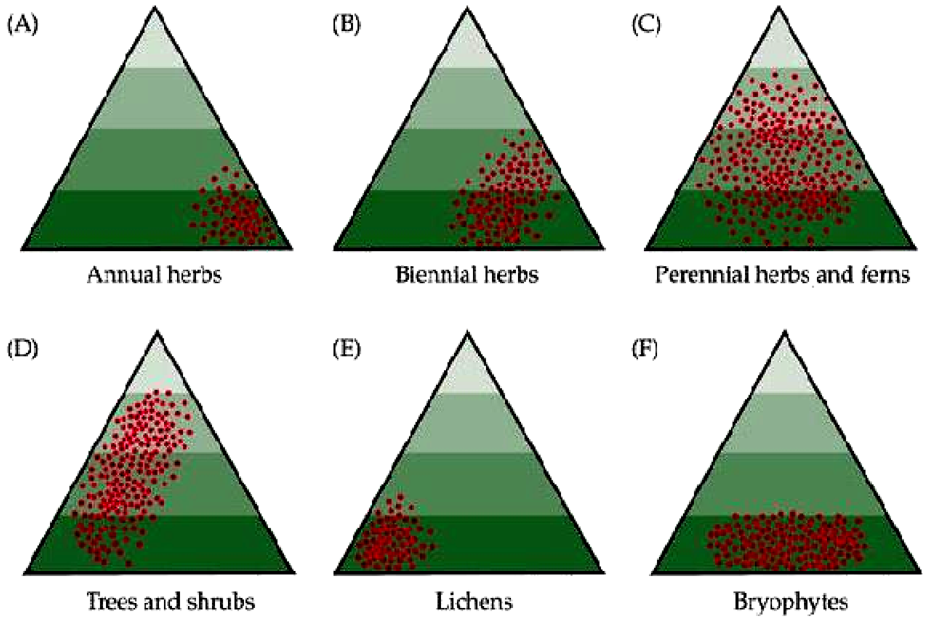
- So there exists a ***r-K* selection continuum** and an organism's position along it in a particular environment at a given time can thus be defined.
- Also, in ecological systems it is highly probable that populations are constantly undergoing *r*- and *K*-selection. Their position on the r-K continuum depends on the strength of selection pressures and where they can balance.
- If some of the populations enter new conditions suitable to a more r- or more K-oriented strategy than a new balance will set up.

**<u>Life history strategies based on Grime's Triangular Model:</u>**




Characteristics of competitive, stress-tolerant & ruderal plants based on Grime'sTriangular Model.

| | Competitive | Stress-tolerant | Ruderal |
|---|---|---|---|
| Growth forms | Perennial herbs, shrubs, or trees | Lichens, perennial herbs, shrubs, and trees | Annuals |
| Seed production | Small | Small | Large |
| Maximum potential growth rate | Rapid | Slow | Rapid |
| Leaf litter | Abundant, often persistent | Little, often persistent | Little, not persistent |
| Leaf longevity | Short | Long | Short |
| Flowering phenology | Flowering near time of maximum productivity | No pattern | Flowering at end of favorable period |
| Vegetative phenology | Leaf production coincides with maximum productivity | Evergreens; various patterns | Brief period of leaf production at time of maximum productivity |
| Life span | Long | Long | Short |




**Population & metapopulation**

**Population**: A population is a group of organisms of the same species occupying a given space at the same time with the mature individuals capable of inter-breeding.

**Metapopulation**: Coined by Richard Levins in 1970 to describe a population consisting of many local populations - population of populations. A metapopulation is a network of populations with scope of occasional movement between them.

**Deme**: A population which is part of a metapopulation.

**Application of the concept of metapopulation**

Very few ecological concepts have received more attention and generated more theoretical and empirical research in recent years than the metapopulation concept. It is a valuable framework in studies concerning the following among many others -

- ✓ Population dynamics of subdivided populations;
- ✓ Conservation of threatened & endangered species;

- ✓ Dynamics of prey-predator systems;
- ✓ Biological control of pest organisms;
- ✓ Competition among plants and animals;
- ✓ Evolution of virulence in host-parasite interactions

**Conditions that define metapopulations**

Although many populations exhibit a patchy spatial distribution there are four necessary conditions tobe met for the concept of metapopulation to be applicable:

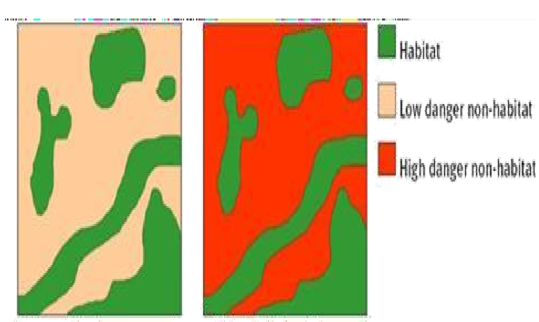
1. The suitable habitat occurs in discrete patches that may be occupied by local breedingpopulations.
2. Even the largest populations have a substantial risk of extinction.
3. Habitat patches should not be too isolated to prevent recolonization after local extinction.
4. The dynamics of local populations are not synchronized

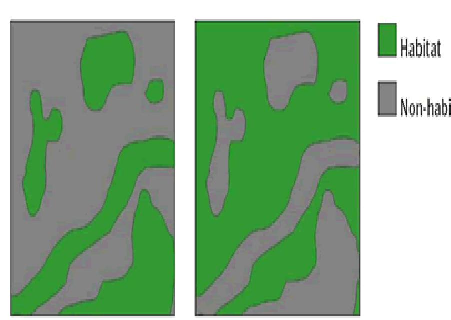
The dynamics of metapopulation differs from population dynamics as it is governed by two sets of processes operating at two distinctive spatial scales:

a. Local or within-patch scale
b. Metapopulation or regional scale

**Colonization and Dispersal:**

- ∗ The process of colonization involves the movement of individuals from occupied patches (existing local populations) to unoccupied patches to form new local populations.
- ∗ Individuals moving from one patch to another typically move across habitat types that are not suitable for their feeding and breeding activities and often with substantial risk of failing to locate another suitable habitat patch in which to settle.



- This dispersal of individuals between local populations is a key feature of metapopulation dynamics. If no individuals move between habitat patches the local populations act independently.
- If the movement of individuals between local populations is sufficiently high, then the local populations will function as a single large population.
- In such a situation, the dynamics of the various local populations may be synchronized and equally susceptible to factors that can lead to possible extinction.
- At intermediate levels of dispersal, a dynamic emerges where the processes of local extinction and recolonization achieve some balance and where the metapopulation exists as a shifting mosaic of occupied and unoccupied habitat patches.
- Metapopulation concept is thus closely linked with the processes of
    - Population turnover
    - Extinction and establishment of new populations
    - And the study of metapopulation dynamics is essentially the study of the conditions under which these two processes are in balance.

**Theory of island biogeography:**

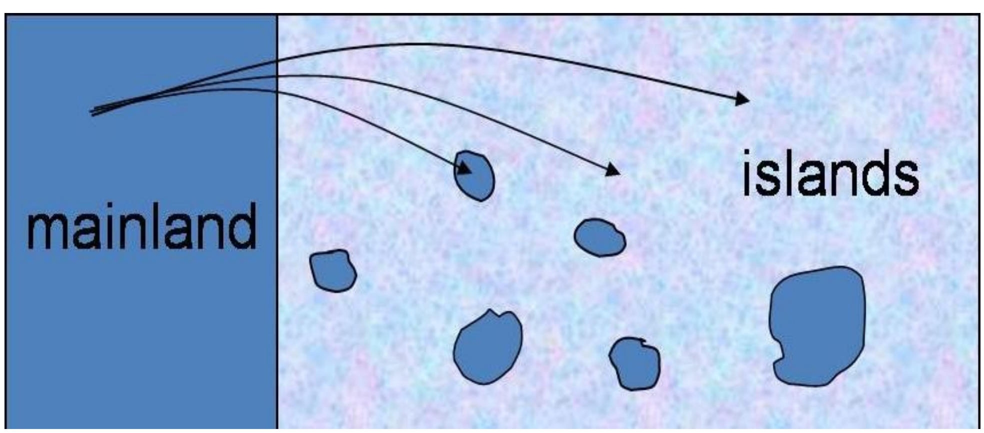
1. In 1967, ecologists Robert MacArthur and E.O. Wilson, coined the Theory of IslandBiogeography.
2. This theory attempted to predict the number of species that would exist on a newly createdisland.
3. It also explained how distance and area combine to regulate the balance betweenimmigration and extinction in an island population.
4. Immigration is the appearance of a species in a community.
5. Extinction is the disappearance of a species from a community.
6. This relationship is known as "species turnover", and it states that the equilibrium value for the island is proportional to the number of

immigrants that come to the island, and the loss of individuals due to emigration and extinction.

7. E.O. Wilson and R. MacArthur did several experiments and made predictions related to theTheory of Island Biogeography.
    i. species richness tends toward an equilibrium value and
    ii. the equilibrium value is the result of immigration, but emigration and extinction may also occur.
8. The equilibrium value (equilibrium diversity value) of an island depends on the area of the island- the larger the area the more resources there are on the island.
9. Smaller islands support smaller populations, andsmaller populations are more likely to become extinct.
10. Here the Target Effect comes in play. The Target Effect says that larger islands have higher immigration rates because they are a bigger target.

**Salient features of mainland-island metapopulation:**

- ❑ Network of populations located within dispersal distance from a very large habitat patch where the local population never goes extinct (hence, metapopulations do not become extinct).
- ❑ Island populations would go extinct without immigrants from mainland population.
- ❑ Danger is in severing islands from mainland populations.



**Habitat Fragmention:**

- ❖ Habitat fragmentation describes a state (or a process) of discontinuities (fragments) within the preferred living area (habitat) of a species.
- ❖ The classical concept of population ecology is that of a single, large and homogeneous population, but now it is widely recognised that most populations are fragmented and heterogeneous.
- ❖ Thus the process of fragmentation has significant implications for ecological and evolutionary processes. Habitat fragmentation involves alteration of habitat resulting in spatial separation of habitat units from a previous state of greater continuity.
- ❖ This phenomenon occurs naturally on a geologic time-scale or in unusual and catastrophic events. Man brings about habitat fragmentation chiefly from agricultural land conversion,
- ❖ urbanization, pollution, deforestation and introduction of alien species.
- ❖ Prior to the dominance of mankind, long term changes brought about by geologic processes orclimate oscillations contributed to habitat fragmentation.

**Important natural phenomena that cause fragmentation:**

- ✓ Glacial advances
- ✓ Volcanic activity
- ✓ Geologic faults & tectonic movement
- ✓ Mass land slumping
- ✓ Major sea level rise
- ✓ Climate oscillation

Each of these actions has the potential to create irreversible effective isolation of previouslyconnected habitat units.

**Anthropogenic factors leading to habitat fragmentation:**

1. Land conversion for agriculture / aquaculture
2. Urbanization
3. Pollution
4. Deforestation
5. Introduction of exotic species
6. Human caused wildfires

**Ecology of fragmented habitats**:

- **Spatial structure:**

Existence of discrete, localised patches of preferred habitat separated by a matrix of non- preferredhabitat.

- **Local demography:**

Small patches are more likely to go extinct and are more variable than large populations.

- **Connectivity:**

Patches are separated by a matrix of non-preferred habitat putting limits on dispersal abilities.

- **Interactions among Populations:**

Plants and animals exhibit a wide range of relationships. Individuals of one species interact with the other individuals of the same species or with those of other species.

**Demes:**

It is a population of organisms within which the exchange of genes is completely random; i.e., all mating combinations between individuals of opposite sexes have the same probability of occurrence.

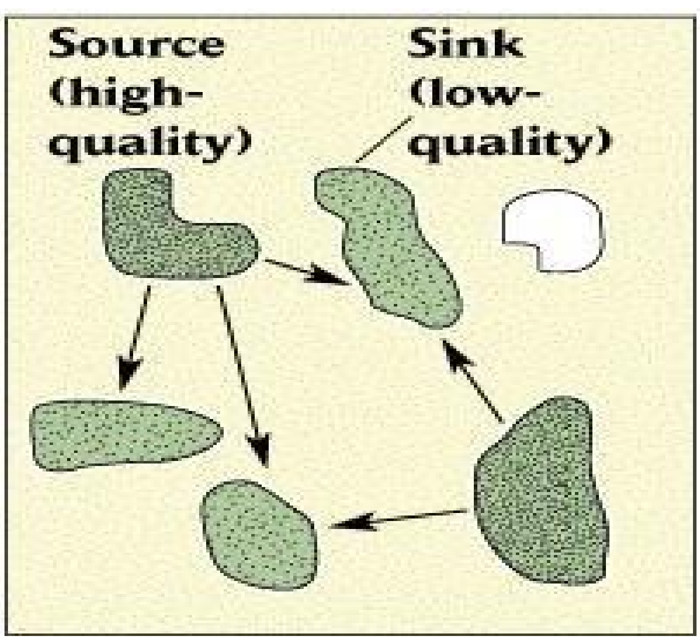
Deme has been used in biology since the 1930s as a term for a local interbreeding population within a species. As such, the recognition of demes can be confused with, and can appear to provide justification for, the existence of biological races or subspecies.

The rationale for naming population units below the species level comes from the simple fact that members of a species are seldom, if ever, evenly distributed throughout the species' geographical range. Uneven distribution can result in clusters of individuals partially isolated from other such clusters—that is, with more interbreeding within the clusters than between them—simply because of proximity. It is to such clusters that the term deme is usually applied. Thus, the green frogs in an isolated pond, a town of prairie dogs, or a field of wild sunflowers might be examples of demes.

If demes inhabit different local environments, natural selection can operate in different directions in these populations with the result that there may be genetic and even physical variation in the characteristics of individual demes. Other processes of evolution, such as mutation and other forms of genetic change, can also enhance these differences, depending upon the extent of demic isolation.

The problem with the concept of the deme is that there is no definitive set of criteria for recognizing demes within species. Normally, some spatial separation or other obvious impediment to genetic exchange is a clue, with genetic or physical distinctions as an expected result. Demes, however, are populations within species, and by definition, exchange genes with other demes of the same species either directly, in the case of adjacent demes, or by a series of steps, in the case of widely separated demes.

**Salient features of Source - Sink model:**

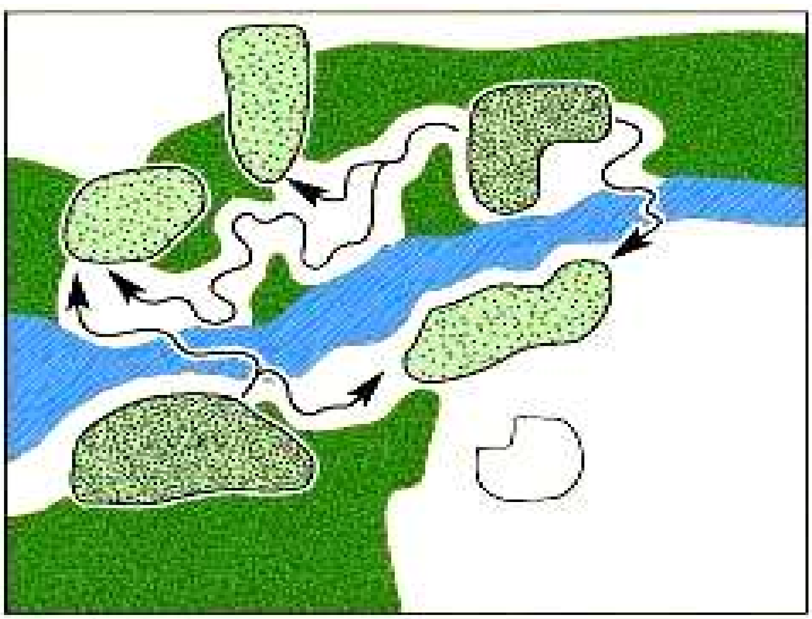


The **source-sink model** of metapopulation dynamics recognizes *differences in the quality* ofsuitable habitat patches.

- in **source patches**, where resources are abundant
  - ✓ individuals produce more offsprings than needed to replace themselves, i.e., positive populationgrowth
  - ✓ surplus offspring disperse to other patches (net export)

- in **sink patches**, where resources are low
  - ✓ populations are maintained by immigration of individuals from elsewhere (net importers)
  - ✓ Negative growth rate without immigration.

**Landscape model:**



➢ The landscape model considers effects of differences in habitat quality within the habitatmatrix.

- The quality of a habitat patch can be affected by the nature of the surrounding matrix.
- Quality is enhanced by presence of resources, such as nesting materials or pollinators.
- Quality is reduced by presence of predators or disease organisms.
- So local extinction rate is a function of both patch suitability and immediate surroundings.
- Some matrix habitats are more easily traversed than others.
- So, local colonization rate is determined not just by proximity of other populations and connectivity but also by other features of the surrounding matrix that may facilitate or impede movement for particular species.

Thus, study of individual movement is key. Such studies allow us to identify barriers to movement and consequently, assess the quality of matrix habitat.

**Various types of population interactions are as follows:**

1. **Neutralism:**

When the presence of one species appears to have no effect on the second species (i.e., no interaction),it is a state of neutralism.

2. **Commensalism:**

It is one-sided relationship between two species in which one species is benefited but the other is neither benefited nor harmed. Some epiphytes, as for example orchids, are the best examples. Epiphytes depend upon the other trees for support and nutrients. They manufacture their own food but do not help supporting plant in any way.

3. **Proto-cooperation:**

It is less extreme type of interaction in which two species interact favorably with each other, thoughboth of them are able to survive separately.

**Table 1.: Population Interactions**

| Species A | Species B | Name of Interaction |
|---|---|---|
| + | + | *Mutualism* |
| – | – | *Competition* |
| + | – | *Predation* |
| + | – | *Parasitism* |
| + | 0 | *Commensalism* |
| – | 0 | *Amensalism* |

**4. Mutualism:**

It is an obligatory interaction that is beneficial to both species. The term symbiosis has also been used for this relationship. Mutualism is best demonstrated in lichens. The lichen is composed of two components—alga and a fungus. The fungus supports the alga while the alga supplies food to fungus. Green Hydra presents another example of mutualism. This animal has green photosynthetic alga in the protective ectoderm. The alga gives off oxygen benefitting the animal which, in turn, supplies CO2 and N2 to the plant. Root nodules of legumes containing Rhizobium leguminasarum bacterium provide another example of mutualism in which there is reciprocal beneficial relationship between the root and bacteria.

**5. Amensalism:**

In this type of interaction between the two species, one species is harmed or inhibited and the other is neither benefitted nor harmed by the association. Many algae produce extracellular toxic metabolites which inhibit the growth of other algae species. Chlorella vulgaris (green alga) produces chlorellin which is toxic to other species of algae.

6. **Parasitism:**

When two organisms live together in which one derives nourishment at the expense of the other, the condition is called parasitism. In the parasitic association, the species which provides nourishment and support is called the host and the one which gets support and nourishment is called the parasite. Several species of plants and animals form parasitic associations with other organisms. A parasite usually parasitizes a host which is larger in body size than it and ordinarily it does not kill the host, at least until it has completed its reproductive cycle.

7. **Cannibalism:**

This type of interaction is limited within a species in which the bigger individuals kill and feed on thesmaller ones. It is a natural method of population control.

8. **Predation:**

In this type of association and interaction one species (predator) kills and feeds on second species (prey). Predation is important process in the community dynamics. Predator is always larger than the prey. From population ecology point of view predation is the action and reaction in the transfer of energy from one trophic level to the other. It represents a direct and complex interaction between two or more species of eaters and eaten.

9. **Competition:**

When in the association of two or more species each species is adversely affected by the presence of the other species in respect of food, shelter, space, light, etc., this phenomenon is termed competition.

It is of two types:

**(i)** **Intraspecific competition:** When competition occurs between the individuals of the same species and their requirements are common, the process is called intraspecific competition.

**(ii)** **Interspecific competition:** In this type of competition, the individuals of different species compete for common materials and conditions.

## 9. Community Ecology: concepts of community, assemblage and guilds; open and closed communities, ecotone; community continuum concept; community structure; measures of community structure – diversity indices, similarity measures, food web analysis; succession - types, mechanisms, concept of climax.

A plant community is a collection or association of plant species within a designated geographical unit, which forms a relatively uniform patch, distinguishable from neighboring patches of different vegetation types. The components of each plant community are influenced by soil type, topography, climate and human disturbance. In many cases there are several soil types within a given phytocoenosis.

A plant community can be described floristically (the species it contains) and/or physiognomically (its physical structure). For example, a forest (a community of trees) includes the overstory, or upper tree layer of the canopy, as well as the understory, further subdivided into the shrub layer, herbaceous layer, and sometimes also moss layer. In some cases of complex forests there is also a well-defined lower tree layer. A plant community is similar in concept to a vegetation type, with the former having more of an emphasis on the ecological association of species within it, and the latter on overall appearance by which it is readily recognized by a layperson.

**Characteristics of Biotic Community:**

Each biotic community consists of very diverse organisms belonging to different kingdoms of living things. The number of species and abundance of population in communities also vary greatly. The organisms in a community depend upon each other as well as upon the non-living environment for food, shelter and reproduction.

**Species Composition:**

The kinds of plants and other organisms present in a community indicate its species composition, which differs from one community to another. Sometimes, in the same community, there may be seasonal variation in plant species.

Each species of community has got definite range of tolerance towards the physical and biological environmental conditions of the habitat. The range of environment a species can tolerate is called its ecological amplitude. The nature of community of a particular habitat is determined by the species, and physical and biotic influences prevailing in the locale of community.

**Dominance:**

A biotic community may have major categories of growth forms, such as trees, shrubs, herbs and mosses. Out of hundreds of species present in the community, relatively only a few exert a major controlling influence due to their large size, numbers of activities.

The phenomenon is called dominance. **"Dominant species are those which are highly successful ecologically and which determine to a considerable extent the conditions under which the associated species must grow."**

The dominance in the community may be the result of co-action between two or more species. Different communities are generally recognized and named on the basis of dominant species occurring in them. For example, a forest community in which pine trees are dominant is called pine forest.

Grassland represents a community which has grass species dominating over the other herbs. Sometimes, communities are named after environmental factors, such as desert community, marine community, mangrove vegetation, etc.

**Physiognomy:**

General appearance of vegetation is referred to as physiognomy. It constitutes general stature, shape and life-forms of the species comprising the vegetation and actually the classification of vegetation types has been done on the basis of physiognomy.

The species of a community can be grouped into several life-forms on the basis of general appearance and growth. The physiognomy is the total effect created by the combination of vertical structure and architecture of dominant species of vegetation.

For example, the high physiognomy of a forest differs distinctly from a low physiognomy of a grassland. However, several communities though possess similar physiognomy, yet differ markedly on the basis of species composition and dominants, e.g., different types of forests.

**Stratification:**

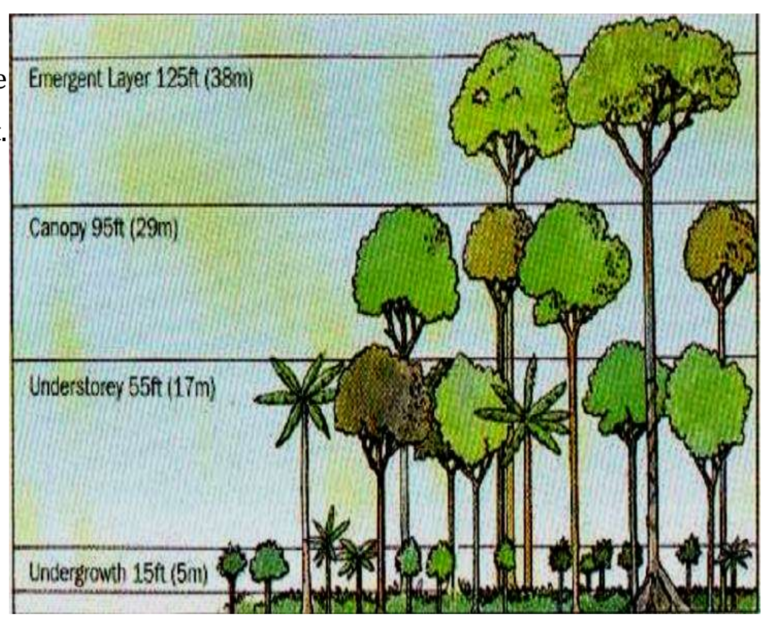
Every biotic community has a vertical layering or stratification of organisms or environmental conditions. A number of examples can be cited to support the concept of community stratification from different habitats.

In grassland community three strata, namely:

(a) Subterranean,
(b) Floor and
(c) Herbaceous may be recognized.

The subterranean stratum contains the roots of the principal vegetation and provides permanent shelter to bacteria, fungi, protozoans, nematodes, earthworms, ringworms and several other invertebrates. The floor stratum consists of basal parts of the vegetation, including the rhizomes of grass plants.

In this stratum, generally the insects, spiders, reptiles and rodents are present. The herbaceous stratum of grassland community is represented by upper parts of grasses and herbs. Several types of insects, birds and grazing mammals are included in this stratum.




In a forest community, five vertical strata are present. They are:

(a) Overstorey stratum,
(b) Understorey stratum,
(c) Transgressive stratum,

(d) Seedling stratum, and

(e) Subterranean stratum.

In pond community, vertical stratification is very little. However, in deep ponds and lakes three strata:

(a) Littoral zone,

(b) Limnetic zone and

(c) Profundal zone can berecognized.

**Species Diversity:**

The biotic community is a natural assemblage of a large number of plant and animal species in an area. However, in any particular habitat there is no considerable variation in environmental condition, the plants growing together in a community show unique uniformity in their behaviour.

Vegetation, therefore, is reflection of a climate and, in general, widely separated areas having similar climate have similar aspects of landscape.

Some communities, for example, tropical rain forest and coral reef community, show high species diversity with many different kinds of species living at each trophic level.

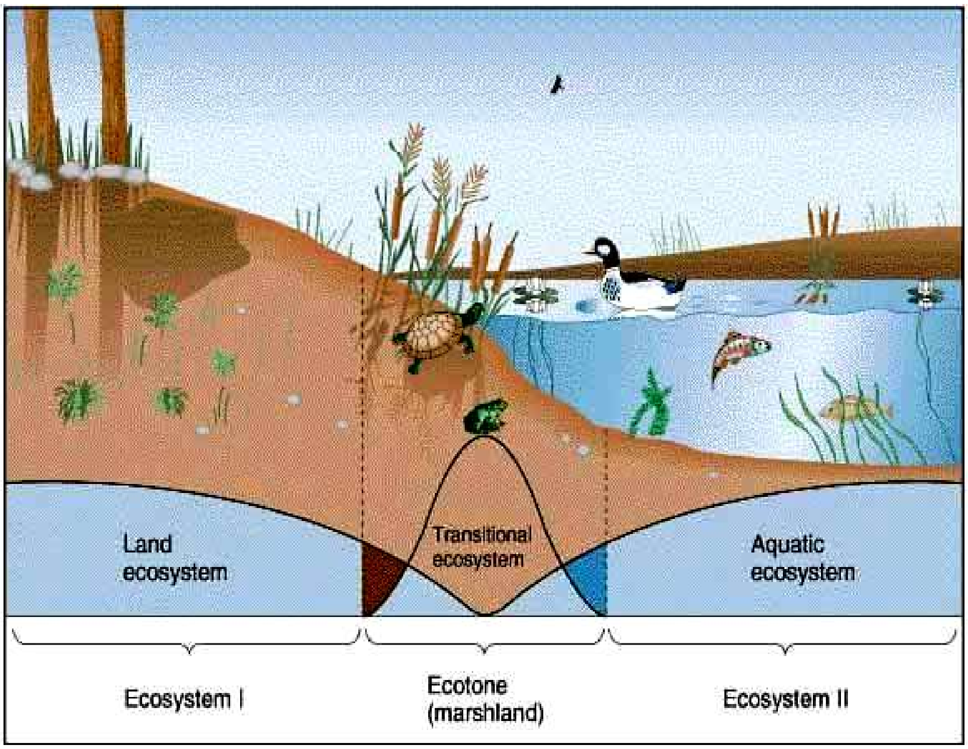
Some community areas have limits but more often the community boundaries are hard to define. A clearly distinguished area or a type of area with uniform habitat conditions and supporting characteristic type of vegetation is termed biotype.

**Ecotone and Edge Effect:**

The zone where two or more different communities meet and integrate, is called transition zone or ecotone. This zone of integration

may be narrow or wide, local (e.g., a zone between field and a forest) or regional (e.g., the transition between forest and grass land). Ecotone containsfew species from both communities. The total number of species is often greater in the ecotone than in the adjoining communities.

The ecotone or transition zone exhibits a shift in dominance of the conspicuous species of both sides. It may also include a number of highly adaptable species that tend to colonize such transitional areas. Because of this, the variety (i.e., species diversity) and density of life is often greatest in such areas.




This potential for the ecotone to act as a habitat for species found in neither major community is called edge effect. Thus the tendency of increased variety and density of some organisms at the community border is known as edge effect.

The organisms that occur primarily, or most abundantly, or spend the greatest amount of their time in junctions between communities are called edge species. A common example of the edge effect in action can be seen in those species of owl that live in or near ecotones between forests and grasslands. They depend on forest trees for nesting and do their hunting in the grassland, where they depend on field rodents for food.

**Keystone Species:**

The species, which have much greater influence on community characteristics, relative

to their low abundance or biomass, are known as keystone species. Such species play a vital role in controlling therelative abundance of other species.
When keystone species is removed, it causes serious disruption in the functioning of the community. For example, in the tropical rain forests, the different species of figs are the keystone species as they produce large quantity of fruits. During the time of food scarcity, these fruits are consumed by monkeys, bats, birds, etc. Thus, by protecting the fig trees, the animals dependent on them are also conserved.

**Link Species:**

However, only a few species act as keystone species, while others act as link species. For example, mycorrhizal fungi in soil are critical link species as they establish essential links in the absorption of nutrients from the soil and other organic substances.
Some critical link species are responsible for providing food to the network species, while others actas pollinators of flowers, and some act as agents for dispersal of seeds and fruits. Tropical rain forests are rich in critical link species due to high degree of animal dependent pollination and dispersal.

1. **Analytic Characters:** They are directly observed or measured in sample plots. They include kinds and number of species,distribution of individuals, number of individuals, height of plants, etc.
2. **Synthetic Characters:** They are derived from the measurements of analytic characters and utilise data obtained in theanalysis of a number of stands.

Analytical characters are of two types:

(i) **Qualitative:** They are based on non-quantitative observations, e.g., species composition and stratification ofvegetation. They are expressed only in qualitative way.

(ii) **Quantitative:** They are expressed in quantitative terms. They are measured. The major quantitative characters include frequency, diversity, cover, biomass, leaf size, abundance, dominance, etc.

They are as follows –

- ***Frequency:***

This is based on percentage of sample plots in which a species is present, indicating its dispersion inspace.

This frequency of each species is calculated as follows:

Frequency percentage = number of sampling units in which that species occurred / number ofsampling units studied X 100

- ***Diversity:***

This is denoted by number of individuals per unit area, indicating the relative abundance of a species.

- ***Cover and Basal Area:***

This is percentage land area occupied by a species, indicating the influence zone of a species. Although sometimes used in general sense for the area occupied by a plant, (which may be the herbage cover or the cover of basal area), it is generally used for above ground parts.

Thus, cover or herbage cover signifies primarily the area of the ground occupied by the above ground parts of plants, such as leaves, stems and inflorescences as viewed from above However, basal area refers to the ground actually penetrated by the stems and is readily seen when theleaves and stems are clipped at the ground surface. It is one of the chief characteristics to determine dominance. It is measured either at 2.5 cm above ground or actually on the ground level.

- ***Biomass:***

This expresses quantity of living materials per unit area, indicating the growth of a species. Thus, biomass is the standing crop expressed in terms of weight (i.e., organism mass) of the living matter present. The amount of living material, present in a component population at any time, is known as the standing crop, which may be expressed in terms of weight per unit area.

- ***Leaf Area:***

The percentages of species having different leaf sizes, indicating the adaptation of the vegetation to the prevailing environment. As the leaves are essential part and are very much affected by climate condition, their shapes and sizes have been taken as important criteria in determination of quantitative characters.

- ***Density:***

Density represents the numerical strength of a species in the community. The number of individualsof that species in any unit area is its density. This gives an idea of degree of competition.

It is calculated as follows:

Density = Number of individuals of the species in all the sampling unit/Total number of samplingunits studied

The value thus obtained is then expressed as number of individuals per unit area.

- ***Abundance:***

This is the number of individuals of any species per sampling unit of occurrence. It is calculated as follows:

Abundance =Total number of individuals of the species in all the sampling units/Number of samplingunits studied

**Synthetic Characters:**

These are determined after computing the data on the quantitative and quantitative characters of the community. For comparing the vegetation of different areas, community comparison needs the calculation of their synthetic characters. These are determined in terms of presence and Constance, fidelity, etc.

- **Presence and Constance:**

It expresses the extent of occurrence of the individuals of a particular species in the community.

- **Fidelity:**

This is the degree with which a species is restricted in distribution to one kind of community. Suchspecies are sometimes known as indicators.

- **Dominance:**

Here, the dominance is expressed in synthetic form. On the basis of density, frequency and dominance(cover) values; there has been proposed idea of Importance Value Index (IVI). IVI of a species in the community give the idea of its relative importance. For IVI, values of Relative density.

Relative frequency and Relative dominance (cover basis) are obtained as follows: Relative density = Density of the species x 100/Total density of all the species Relative Frequency = Frequency of the species x 100/Total frequency of all the species

Relative dominance (cover) = Dominance (cover) of the species x 100/Total dominance (cover) of allthe species

Now for IVI, three values are added. IVI values of different species are then arranged in decreasingorder.

**Other Synthetic Characters:**

In addition to above mentioned characters, there are some other synthetic characters. They are quite useful in comparative studies on communities. Such characters include, interspecific association and association index, index of similarity, dominance index, species diversity and diversity index, etc.

**Life Forms:**

Life forms better known as Raunkiaer's life forms or Botanical Life Forms were proposed in 1934 bya Danish botanist Christen C. Raunkiaer. According to Raunkiaer, in a community it is very important to know how a plant survives during unfavourable conditions. He took the criterion of protection of perennating buds during adverse conditions as an adaptation of plant to climate. Accordingly he proposed a system known as Raunkiaer's system in which plants were categorized into various life forms based on the position of their budsduring seasons of unfavourable conditions (too much cold or too much hot). Raunkiaer considered five major types of life forms viz. Phanerophytes, Chamaephytes, Hemicryptophytes, Cryptophytes, and Therophytes.

**1. Phanerophytes** (Phanero – visible; phytes – plants; plants where buds are visible): These are those plants whose buds are situated high up on the plant on the top of the shoots. These are either naked or covered with scales. Phanerophytes are very common in tropical areas and their number decreases towards temperate and polar areas. Based on the height of trees, phanerophytes are further divided into 4 categories:

a) Mega-phanerophytes – trees taller than 30 m

b) Meso-phanerophytes – trees between 8 – 30 m

c) Micro-phanerophytes – trees between 2 – 8 m height

d) Nano-phanerophytes – shrubs shorter than 2 m but more than 25 cm

**2. Chamaephytes:** These are those plants whose buds are close to ground or maximum up to 25 cm. These plants are found in colder regions at high altitudes or latitudes, e.g. Temperate America. During the growing season, sometimes the aerial parts of chamaephytes die and cover the buds. Fresh growth occurs during the onset of favourable season.

**3. Hemicryptophytes:** These are also found in the cold regions where buds remain covered under surface soil (but not deep-seated), and are protected. These include annual (plants which complete their life cycle in one year or one season) or biennial (which complete their life cycle in 2 years or 2 seasons) herbs.

**4. Cryptophytes:** These are also known as Geophytes. In these plants, the buds remain buried under soil such as bulbs and rhizomes. Such plants are mostly found in the arid regions of the world.

**5. Therophytes:** These are the ephemerals or seasonal plants that complete their life cycle quickly under favourable conditions and during the rest of the unfavourable conditions remain in the form of seeds.

Besides these five major categories, Raunkiaer also identified epiphytes (plant growing on or attachedto other plants) as a separate category of life forms. Additionally, he also divided cryprophytes into three subtypes: geophytes (plants buried in soil with subterranean or perennating buds), hydrophytes (plants submerged or floating in aquatic systems with perennating buds inside water), and halophytes (plants in marshy swampy areas with high salt concentrations).

**Guilds:**

A guild (or ecological guild) is any group of species that exploit the same resources, or that exploit different resources in related ways. It is not necessary that the species within a guild occupy the same, or even similar, ecological niches. An ecological niche is defined as the role an organism plays in its community, i.e. decomposer, primary producer, etc. Guilds are defined according to the locations, attributes, or activities of their component species. For example, the mode of acquiring nutrients, the mobility, and the habitat zones that the species occupy or exploit can be used to define a guild. The number of guilds occupying an ecosystem is termed its disparity. Members of a guild within a given ecosystem could be competing for resources, such as space or light, while cooperating in resisting wind stresses, attracting pollinators, or detecting predators, such as happens among savannah- dwelling antelope and zebra.

**Open and Closed community:**

Henry Allan Gleason (1882–1975) was an American ecologist, botanist, and taxonomist, known for his endorsement of the individualistic or open community concept of ecological succession, and his opposition to Frederic Clements's concept of the climax state of an ecosystem.

A closed community intentionally limits links with outsiders and outside communities. Closed communities may be of a religious, ethnic, or political nature. Governance of closed societies varies. Typically, members of closed communities are either born into the community or are accepted into it The opposite of a closed community is an open community, which maintains social relations withexternal communities.

Frederic Clements was an American ecologist and pioneer who studied vegetation formation and development, he created the idea that plants are supposed to birth, grow/mature, and decay. Their life cycle is similar to that of a human being. Clements also tested a theory known as "climax community"

**Diversity indices:**

A diversity index (also called phylogenetic indices or phylogenetic metrics) is a quantitative measure that reflects how many different types (such as species) there are in a dataset (a community) and that can simultaneously take into account the phylogenetic relations among the individuals distributed among those types, such as richness, divergence or evenness.

**Species Richness:**

The simplest way to describe a community is to list the species in it. Species richness (S) is the number of species on that list, and is most often used as the first pass estimate of diversity for a community.

How would one generate such a list? A simple and widely used method is to define the boundaries of the community and then walk through it seasonally, noting all the species you encounter. This is what we call a flora.

**Simpson's Index:**

Simpson's Index is considered a dominance index because it weights towards the abundance of themost common species.

Simpson's Index gives the probability of any two individuals drawn at random from an infinitely largecommunity belonging to different species.

For example, the probability of two trees, picked at random from a tropical rainforest being of thesame species would be relatively low, whereas in boreal forest in Canada it would be relatively high.

The range is from 0 to 1, where:

> High scores (close to 1) indicate high diversity. Low scores (close to 0) indicate low diversity.

The bias corrected form of Simpson's Index is:

$$D_S = \sum_{i=1}^{S} \frac{\left(n_i \left(n_i - 1\right)\right)}{\left(N\left(N-1\right)\right)}$$

Where, ni is the number of individuals in the ith species.

Since Ds and diversity are negatively related, Simpson's index is usually expressed as the reciprocal (1-D) so that as the index goes up, so does diversity.

## Simpson's Index

A worked example for 201 trees of 5 species assessed in several quadrats:

| Tree spp. | No. Individuals |
|---|---|
| A | 100 |
| B | 50 |
| C | 30 |
| D | 20 |
| E | 1 |
| Total | 201 |

$$D_S = \left(\frac{100\times 99}{201\times 200}\right)+\left(\frac{50\times 49}{201\times 200}\right)+\ldots\left(\frac{1\times 0}{201\times 200}\right)=0.338$$

Then $1/D = 1/0.388 = 2.96$

**Shannon-Weiner Index:**

The Shannon-Weiner Index belongs to a subset of indices that maintain that diversity can be measuredmuch like the information contained in a code or message (hence the name information index).

The rationale is that if we know a letter in a message, we can know the uncertainty of the next letter ina coded message (i.e., the next species to be found in a community).

The uncertainty is measured as H', the Shannon Index. A message coded bbbbbb has low uncertainty(H' = 0).

The Shannon Index assumes that all species are represented in a sample and that the sample wasobtained randomly: Si i

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where, pi is the proportion of individuals found in the $i^{th}$ species and ln is the natural logarithm.

| | Species | Abund | $p_i$ | $p_i \ln p_i$ |
|---|---|---|---|---|
| | A | 50 | 0.5 | -0.347 |
| | B | 30 | 0.3 | -0.361 |
| | C | 10 | 0.1 | -0.230 |
| | D | 9 | 0.09 | -0.217 |
| | E | 1 | 0.01 | -0.046 |
| Total | 5 | 100 | 1.00 | -1.201 |

H' = 1.201

**Similarity Indices -** measure similarity between communities based on species composition.

**Binary Similarity Coefficients:**

The simplest similarity measures deal only with presence-absence data. The basic data for calculatingbinary (or association) coefficients is a 2x2 table:

| | | Sample A: No. of species present | Sample A: No. of species absent |
|---|---|---|---|
| Sample B | No. of species present | *a* | *b* |
| | No. of species absent | *c* | *d* |

where:

*a* = Number of species in sample A and sample B (joint occurences)
*b* = Number of species in sample B but not in sample A
*c* = Number of species in sample A but not in sample B
*d* = Number of species absent in both samples (zero-zero matches)

**Jaccard coefficient:**

$$S_j = \frac{a}{a + b + c}$$

Where, $S_j$ = Jaccard similarity coefficient

a = number of species common to (shared by) quadrats,

b = number of species unique to the first quadrat, and

c = number of species unique to the second quadrat

**Sørensen coefficient:**

$$S_S = \frac{2a}{2a + b + c}$$

Where, $S_S$ = Sorensen's similarity coefficient

This index can also be modified to a coefficient of dissimilarity by taking its inverse: Sorensen's dissimilarity coefficient 1 - Ss

This coefficient weights matches in species composition between the two samples more heavily than mismatches. Whether or not one thinks this weighting is desirable will depend on the quality of the data. If many species are present in a community but not present in a sample from that community, it may be useful to use Sorensen's coefficient rather than Jaccard's. But the Sorensen and Jaccard coefficients are very closely correlated.

**Simple Matching Coefficient:**

This is the simplest coefficient for binary data that makes use of negative matches as well as positive matches. It is not used very frequently because for most data sets negative matches are not biologically meaningful.

$$S_{SM} = \frac{a+d}{a+b+c+d}$$

where $S_{SM}$ = Simple matching similarity coefficient

**Succession:**

Ecological succession is the process of change in the species structure of an ecological community over time. The time scale can be decades (for example, after a wildfire), or even millions of years after a mass extinction.

The community begins with relatively few pioneering plants and animals and develops through increasing complexity until it becomes stable or self-perpetuating as a climax community. The "engine" of succession, the cause of ecosystem change, is the impact of established species upon their own environments. A consequence of living is the sometimes subtle and sometimes overt alteration ofone's own environment.

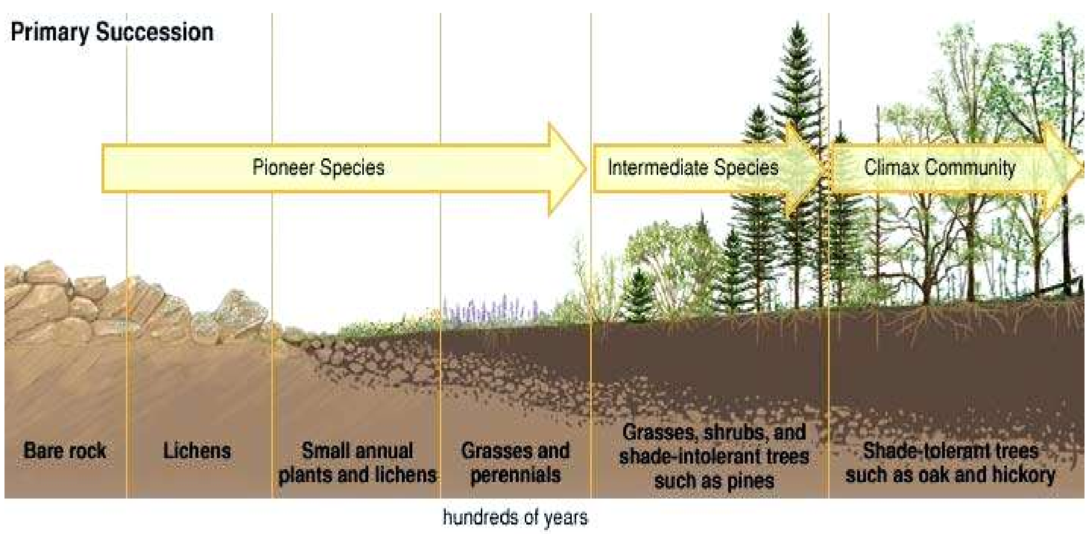
It is a phenomenon or process by which an ecological community undergoes more or less orderly and predictable changes following a disturbance or the initial colonization of a new habitat. Succession may be initiated either by formation of new, unoccupied habitat, such as from a lava flow or a severe landslide, or by some form of disturbance of a community, such as from a fire, severe wind throw, or logging. Succession that begins in new habitats, uninfluenced by pre-existing communities is called primary succession, whereas succession that follows disruption of a pre-existing community is called secondary succession.

**Primary, secondary and cyclic succession:**

Successional dynamics beginning with colonization of an area that has not been previously occupied by an ecological community, such as newly exposed rock or sand surfaces, lava flows, newly exposed glacial tills, etc., are referred to as primary succession. The stages of primary succession include pioneer plants (lichens and mosses), grassy stage, smaller shrubs, and trees. Animals begin to return when there is food there for them to eat. When it is a fully functioning ecosystem, it has reached the climax community stage.

Successional dynamics following severe disturbance or removal of a pre-existing community are called secondary succession. Dynamics in secondary succession are strongly influenced by pre- disturbance conditions, including soil development, seed banks, remaining organic matter, and residual living organisms. Because of residual fertility and pre-existing organisms, community change in early stages of secondary succession can be relatively rapid. In a fragmented old field habitat created in eastern Kansas, woody plants "colonized more rapidly (per unit area) on large and nearby patches.

Secondary succession is much more commonly observed and studied than primary succession. Particularly common types of secondary succession include responses to natural disturbances such as fire, flood, and severe winds, and to human-caused disturbances such as logging and agriculture. As an example, secondary succession has been occurring in Shenandoah National Park following the 1995 flood of the Mormon River, which destroyed plant and animal life. Today, plant and animal species are beginning to return.




**Causes of plant succession:**

**Autogenic succession** can be brought by changes in the soil caused by the organisms there. These changes include accumulation of organic matter in litter or humic layer, alteration of soil nutrients, or change in the pH of soil due to the plants growing there. The structure of the plants themselves can also alter the community. For example, when larger species like trees mature, they produce shade onto the developing forest floor that tends to exclude light- requiring species. Shade-tolerant species willinvade the area.

**Allogenic succession** is caused by external environmental influences and not by the vegetation. For example, soil changes due to erosion, leaching or the deposition of silt and clays can alter the nutrient content and water relationships in the ecosystems. Animals also play an important role in allogenic changes as they are pollinators, seed dispersers and herbivores. They can also increase nutrient content of the soil in certain areas, or shift soil about (as termites, ants, and moles do) creating patchesin the habitat. This may create regeneration sites that favor certain species.

**Autotrophic and Heterotrophic Succession:**

A succession in which green plants or the autotrophs dominate, so that there is a continuous energy flow during the whole process, is known as Autotrophicsuccession. In contrast, succession wherein heterotrophs such as bacteria, fungi, actinomycetes or even animals dominate and there is a continuous decline in the energy flow is known as Heterotrophicsuccession.

Further, based on the nature of environment (primarily moisture conditions) at the start of thesuccession, the succession can be of following types:

- **Hydrarch or Hydrosere:** If the succession begins from a water body, it is termed as Hydrosere or Hydrarch. The water body could be lake, pond, stream, bog or even the swampy area.
- **Xerosere or Xerarch:** In this case, the succession begins from the dry conditions with very little moisture content, for example, a desert area, sandy areas, rocks etc. If specifically the succession starts from the rocky areas, it is known as Lithosere, whereas if it starts from a sand dune it is known as Psammosere.
- **Mesosere or Mesarch:** If the succession starts in an area with adequate moisture conditions and temperature, it is known as mesosere or mesarch.

❖ **Halosere:** Halosere is a type of succession occurring in a saline area i.e. where concentration of salt inthe substratum is very high.

**Process of Hydrosere:**

A hydrosere, also known as hydrarch, starts from a water body like pond, lake or pool that is gradually convertedinto a forest through an orderly process. The various plant communities come in sequence during this succession are grouped into seven main stages as follows:

1. Phytoplankton stage (pioneer stage)
↓
2. Rooted Submerged stage (seral stage 1)
↓
3. Rooted Floating stage (seral stage 2)
↓
4. Reed Swamp stage (seral stage 3)
↓
5. Sedge-Meadow stage (seral stage 4)
↓
6. Woodland stage (seral stage 5)
↓
7. Forest stage (climax stage)

**Process of Lithosere, a type of Xerosere:**

This type of succession starts from a rock, which is in un-weathered state and lacks any organic matter or moisture content. At this stage, only the simple plants like lichens can colonize. The lichens are then followed by various other plants that contribute towards building up of the soil substratum congenial for supporting a mature forest community. Various plant communities that colonize in succession one after the other are summarized as under:

**Crustose lichen stage (pioneer stage)**

↓

**Foliose lichen stage (seral stage 1)**

↓

**Moss stage (seral stage 2)**

↓

**Herb stage (seral stage 3)**

↓

**Shrub stage (seral stage 4)**

↓

**Forest stage (Climax stage)**

**General process of succession:**

The entire process of primary autotrophic succession is completed through a series of sequential steps followed by one after another.

The different sequential steps may be outlined as below:

**1 Nudation:**

It is a process of developing a bare area without any form of life for the arrival of new species. Thecauses of nudation may be:

- **a) Topographic:** The existing community may disappear due to soil erosion (by gravity, water or wind), land slide,volcanic activity etc.
- **b) Climatic:** The existing community may be destroyed due to storm, fire, frost, drought.
- **c) Biotic:** The community may also be destroyed by anthropogenic activities like destruction of forest, destruction of grass land etc. Besides, diseases induced by bacteria and virus can also destroy the population.

**2. Invasion:**

The successful establishment of a species in a bare area is called as invasion. This process of establishment is completed in three successive steps:

- **a) Migration (dispersal):** The seeds, spores or other progagules of the species are brought to the bare area by the agents like air, water etc.
- **b) Ecesis (Establishment):** The process of successful establishment (germination and growth) of the species in the new area as a result of

adjustment with the prevailing conditions is known as ecesis.

c) **Aggregation:** After ecesis, the individuals of species increase their number by reproduction and thus, are aggregatedin a particular area.

**3. Competition and Coaction:**

As the species aggregate at a limited space, there happens competition (inter as well as intra specific) mainly for space and nutrition. Secondly the life process of one individual is affected by the surrounding species in various ways which is known as coaction. The species which are found unable to compete with others in the existing environment get discarded.

**4. Reaction:**

The species present in an environment constantly interact with it there by causing its modification. The mechanism of the modification of the environment through the influence of living organisms on it, is known as reaction.

Reaction induces changes in soil composition, water content and light organisms on it and is known asreaction. Reaction induces changes in soil composition, water content, light conditon, temperature etc.Due to drastic modifications of the environment/ it may not be suitable for the existing community.

Hence, the existing community may be replaced by another community. The whole sequence of communities that substitute one another in the given area is known as sere and the various communities constituting the sere are known as seral communities or seral stages.

**5. Stablisation (Climax):**

At last a final or terminal community is established. Which is stabilized for a longer period of time and which can maintain an equilibrium with the environment of that area. This community is knownas climax community and the stage is as climax stage.

**Concept of Climax community:**

In ecology, climax community is a historic term for a biological community of plants, animals, and fungi which, through the process of ecological succession in the development of vegetation in an area over time, have reached a steady state. This equilibrium was thought to occur because the climax community is composed of species best adapted to average conditions in that area. The term is sometimes also applied in soil development. Nevertheless, it has been found that a "steady state" is more apparent than real, particularly if long-enough periods of time are taken into consideration. Notwithstanding, it remains a useful concept.

The idea of a single climatic climax, which is defined in relation to regional climate, originated with Frederic Clements in the early 1900s. The first analysis of succession as leading to something like a climax was written by Henry Cowles in 1899, but it was Clements who used the term "climax" to describe the idealized endpoint of succession.

**Characteristics:**

- The vegetation is tolerant of environmental conditions.
- It has a wide diversity of species, a well-drained spatial structure, and complex food chains.
- The climax ecosystem is balanced. There is equilibrium between gross primary production and total respiration, between energy used from sunlight and energy released by decomposition, between uptake of nutrients from the soil and the return of nutrient by litter fall to the soil.
- Individuals in the climax stage are replaced by others of the same kind. Thus the species composition maintains equilibrium.

It is an index of the climate of the area. The life or growth forms indicate the climatic type.

**Types of climax Climatic Climax:**

If there is only a single climax and the development of climax community is controlled by the climate of the region, it is termed as climatic climax. For example, development of Maple-beech climax community over moist soil. Climatic climax is theoretical and develops where physical conditions of the substrate are not so extreme as to modify the effects of the prevailing regional climate.

**Edaphic Climax:**

When there are more than one climax communities in the region, modified by local conditions of the substrate such as soil moisture, soil nutrients, topography, slope exposure, fire, and animal activity, it is called edaphic climax. Succession ends in an edaphic climax where topography, soil, water, fire, or other disturbances are such that a climatic climax cannot develop.

**Catastrophic Climax:**

Climax vegetation vulnerable to a catastrophic event such as a wildfire. For example, in California, chaparral vegetation is the final vegetation. The wildfire removes the mature vegetation and decomposers. A rapid development of herbaceous vegetation follows until the shrub dominance is re- established. This is known as catastrophic climax.

**Disclimax:**

When a stable community, which is not the climatic or edaphic climax for the given site, is maintained by man or his domestic animals, it is designated as Disclimax (disturbance climax) or anthropogenic subclimax (man-generated). For example, overgrazing by stock may produce a desert community of bushes and cacti where the local climate actually would allow grassland to maintain itself.

**Subclimax:**

The prolonged stage in succession just preceding the climatic climax is subclimax.

**Preclimax and Postclimax:**

In certain areas different climax communities develop under similar climatic conditions. If the community has life forms lower than those in the expected climatic climax, it is called preclimax; a community that has life forms higher than those in the expected climatic climax is postclimax. Preclimax strips develop in less moist and hotter areas, whereas Postclimax strands develop in more moist and cooler areas than that of surrounding climate.

**Theories:**

There are three schools of interpretations explaining the climax concept,

- **Monoclimax or Climatic Climax Theory** was advanced by Clements (1916) and recognizes only one climax whose characteristics are determined solely by climate (climatic climax). The processes of succession and modification of environment overcome the effects of differences in topography, parent material of the soil, and other factors. The whole area would be covered with uniform plant community. Communities other than the climax are related to it, and are recognized as subclimax, postclimax and disclimax.

- **Polyclimax Theory** was advanced by Tansley (1935). It proposes that the climax vegetation of a region consists of more than one vegetation climaxes controlled by soil moisture, soil nutrients, topography, slope exposure, fire, and animal activity.
- **Climax Pattern Theory** was proposed by Whittaker (1953). The climax pattern theory recognizes a variety of climaxes governed by responses of species populations to biotic and abiotic conditions. According to this theory the total environment of the ecosystem determines the composition, species structure, and balance of a climax community. The environment includes the species responses to moisture, temperature, and nutrients, their biotic relationships, availability of flora and fauna to colonize the area, chance dispersal of seeds and animals, soils, climate, and disturbance such as fire and wind. The nature of climax vegetation will change as the environment changes. The climax community represents a pattern of populations that corresponds to and changes with the pattern of environment. The central and most widespread community is the climatic climax.

The theory of alternative stable states suggests there is not one end point but many which transition between each other over ecological time.

## 10. Ecosystem Ecology: concept of ecosystem, disturbance (natural and anthropogenic) and their impact on plant ecology; invasive plant

**species; resistance and resilience of ecosystems.**

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**Ecosystem:**

Ecology deals with the study of interactions between living organisms and their physical environment. Now ecology is defined as the study of ecosystems. The term ecosystem was proposed by A.C. Tansley in 1935 where ecoimplies the environment and system denotes an interacting, interdependent,integrated complex.

Ecosystem may be defined as the system resulting from the integration of all living and non-living factors of the environment. Thus any structural and functional unit of biosphere where the organisms interact with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycle (i.e., exchange of materials between living and non-living components) within the system is known as an ecological system or ecosystem.

Earth is a giant ecosystem where abiotic and biotic components are constantly acting and reacting with each other bringing structural and functional changes in it. This vast ecosystem-biosphere is subdivided into units of smaller ecosystems such as terrestrial and aquatic ecosystems.

These systems may be freely exchanging energy and matter from outside—an open ecosystem or maybe isolated from outside—a closed ecosystem.

An ecosystem is normally an open system with a continuous but variable influx and loss of material and energy. It is a basic, functional unit with no limits of boundaries.

Thus an ecosystem represents the highest level of ecological integration which is energy based and this functional unit is capable of energy transformation, accumulation and circulation. Its main function in ecological sense is to emphasize obligatory relationships, interdependence and casual relations.

**Classification of Ecosystems:**

**1. Natural Ecosystems:**

These systems operate by themselves under natural conditions without any major interference by man.These are further divided into following ecosystems:

(i) **Terrestrial ecosystem** includes forests, grasslands and deserts etc.

(ii) **Aquatic ecosystem** may be further distinguished as

a) Fresh water which may be lotic (running water as springs, streams or rivers) or lentic (standing water as lakes, ponds, pools, ditches, puddles, swamps etc.).

b) Marine water such as oceans (deep bodies) or seas or estuaries (shallow ones).

**2. Artificial (Man-engineered) Ecosystems:**

These are maintained artificially by man where, by addition of energy and planned manipulations, natural balance is disturbed regularly. Crop, urban, industrial, space and control of biotic community as well as the physico-chemical environment are man-engineered ecosystems.

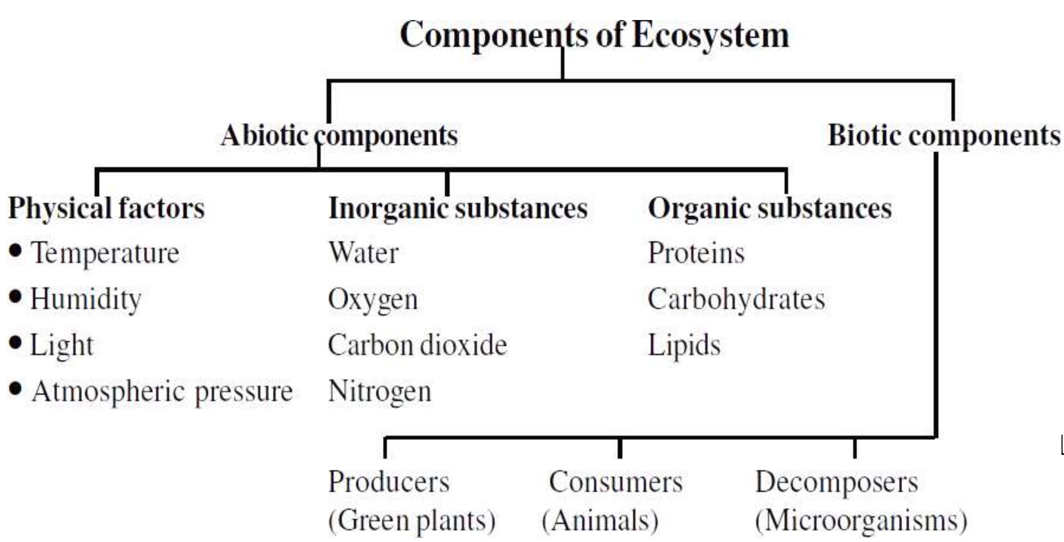
**3. Space Ecosystem** is also recognised as one of ecosystems and play a very important role in human life.The common features of all ecosystems — terrestrial, aquatic and agricultural are the interactions of the autotrophic and heterotrophic components.

**Components of Ecosystem:**

An ecosystem has two major components—biotic and abiotic.

**(A) Biotic (Living) Components:**

Plants, animals and micro-organisms having different nutritional behaviour constitute the bioticcomponents of an ecosystem.



1. **Producers (Autotrophs):**

Producers are mainly chlorophyll bearing green plants (photo autotrophs) which can synthesize their food in presence of sunlight making use of $CO_2$ and water through the process of photosynthesis. Since plants convert solar energy into chemical energy so they must be better called converters or transducers. Chemosynthetic organisms or chemo-autotrophs can also synthesize some organic matter by the oxidation of certain chemicals in absence of sunlight.

2. **Consumers (or Heterotrophs or Phagotrophs):**

Consumers consume the matter built up by the producers. They utilise, rearrange and decompose complex materials.

Consumers are of the following types:

**(i) Herbivores:**

They feed directly on producers and hence are known as primary consumers, e.g., rabbit, deer, cattle, insects etc. Elton (1927) called herbivores as key industry animals because they convert plants into animal materials.

**(ii) Carnivores (Meat eaters):**

They feed on other consumers. If they feed on herbivores, they are called secondary consumers (e.g., frog, birds, cat) and if they prey on other carnivores (snake, peacock), they are known as tertiary carnivores/consumers. Lion, tiger etc. which cannot be preyed are called top carnivores since they occupy top position in the food chain.

**(iii) Omnivores:**

They feed both on plants and animals, e.g., rat, fox, birds and man.

**(iv) Detritivores (Detritus feeders or saprotrophs):**

They feed on partially decomposed matter such as termites, ants, crabs, earthworms etc.

3. **Decomposers (or Micro-consumers):**

Decomposers are saprophytic (osmotrophs) micro-organisms such as bacteria, actinomycetes and fungi. They derive their nutrition by breaking down complex organic compounds and release inorganic nutrients into environment, making them available again to producers.

The biotic components of any ecosystem may be thought of as the functional kingdom of nature, since they are based on the type of nutrition and the energy source used. The entire earth is considered as an ecosystem which is referred to as biosphere or ecosphere.

**(B) Abiotic (Non-living) Components:**

Structurally abiotic components include:

**1) Climatic regime:**

Precipitation, temperature, sunlight, intensity of solar flux, wind etc. have a strong influence on theecosystem.

**2) Inorganic substances:**

These are C, N, H, O, P, S involved in material cycles. The amount of these substances present in anecosystem is known as standing state or standing quality.

**3) Organic Substances:**

Carbohydrates, proteins, lipids and humic substances link the abiotic components with the biotic components. All the biotic and abiotic components of an ecosystem are influenced by each other and are linked together through energy flow and matter cycling.

**Functions of ecosystem:**

Ecosystems are complex dynamic system. They perform certain functions. These are:-

(i) Energy flow through food chain

(ii) Nutrient cycling (biogeochemical cycles)

(iii) Ecological succession or ecosystem development

(iv) Homeostasis (or cybernetic) or feedback control mechanisms

Ponds, lakes, meadows, marshlands, grasslands, deserts and forests are examples of natural ecosystem. Many of you have seen an aquarium; a garden or a lawn etc. in your neighbourhood. These are man made ecosystem.

Ecosystem is the functional unit of nature where living organisms interact among themselves and also with the surroundings physical environment.

There are two basic categories of ecosystem, namely the terrestrial and the aquatic.

**Terrestrial ecosystem –** forest, grassland, desert etc.

**Aquatic ecosystem** – ponds, lake, river, estuary etc.

**Pond as an example of an ecosystem:**

A pond is an example of a complete, closed and an independent ecosystem. It is convenient to study its basic structure and functions. It works on solar energy and maintains its biotic community in equilibrium. If you collect a glass full of pond water or a scoop full of pond bottom mud, it consists ofa mixture of plants, animals, inorganic and organic materials. Following components are found in a pond ecosystem.

**1) Abiotic components**

**(i) Light:** Solar radiation provides energy that controls the entire system. Penetration of light depends on transparency of water, amount of dissolved or suspended particles in water and the number of plankton. On the basis of extent of penetration of light a pond can be divided into euphotic (eu=true,photic=light), mesophotic and aphotic zones. Plenty of light is available to plants and animals in euphotic zone. No light is available in the aphotic zone.

**(ii) Inorganic substances:** These are water, carbon, nitrogen, phosphorus, calcium and a few other elements like sulphur depending on the location of the pond. The inorganic substances like $O_2$ and $CO_2$ are in dissolved state in water. All plants and animals depend on water for their food and exchange of gases- nitrogen, phosphorus, sulphur and other inorganic salts are held in reserve in bottom sediment and inside the living organisms. A very small fraction may be in the dissolved state.

**(iii) Organic compounds:** the commonly found organic matters in the pond are amino acids and humic acids and the breakdown products of dead animals and plants. They are partly dissolved in water and partly suspended in water.

**2) Biotic components**

**(i) Producers or autotrophs:** synthesize food for all the heterotrophs of the pond. They can becategorized into two groups:-

***(a)*** *Floating microorganisms and plants*

***(b)*** *Rooted plants*

**(a)** Floating microorganisms (green) and plants are called phytoplankton ("phyto"- plants, "plankton"–floating). They are microscopic organisms. Sometimes they are so abundant in pond that they makeit look green in colour e.g. *Spirogyra*, *Ulothrix*, *Cladophora*, Diatoms, *Volvox*.

**(b)** **Rooted plants:** These are arranged in concentric zones from periphery to the deeper layers. Three distinct zones of aquatic plants can be seen with increasing deapth of water in the following order:

I. **Zone of emergent vegetation:** . eg. *Typha*, *Bulrushes* and *Sagittaria*

II. **Zone of rooted vegetation with floating leaves** . eg. *Nymphaea*

III. **Zone of submergent vegetation:** eg. All pond weeds like *Hydrilla* , *Rupia*, musk grass etc.

**(ii) Consumers/Heterotrophs** are animals which feed directly or indirectly on autotrophs eg.Tadpole, snails, sunfish, bass etc.

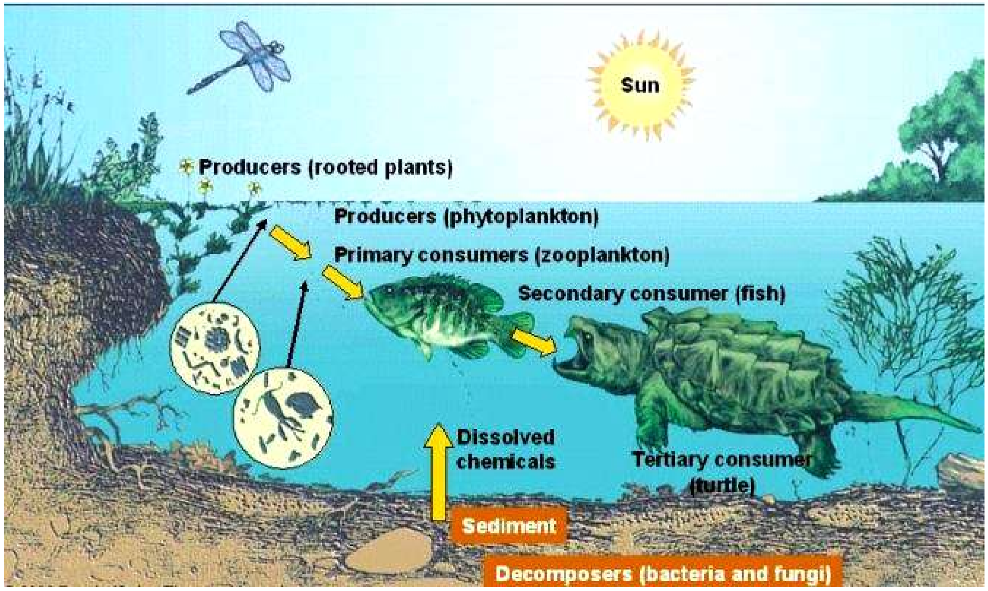
Pond animals can be classified into the following groups

**(a)** **Zooplanktons are floating animals. *Cyclops, Cypris***

**(b)** **Nektons are the animals that can swim and navigate at will. Eg. fishes**

**(c)** **Benthic animals are the bottom dwellers: beetle, mites, mollusks and some crustaceans.**

**(iii) Decomposers:** They are distributed through out the entire in the whole pond but in the sediment most abundant. There are bacteria and fungi. (*Rhizopus*, *Penicillium*, *Curvularia* ,*Cladosporium*) found at the bottom of the pond.




**Measuring Production:**

The bulk of any ecosystem is plants compared to which only a small fraction is animal life. Therefore, measurement of energy of an ecosystem primarily involves plants. And because plants represent the first or primary trophic level, plant production is measured as **Gross Primary Production**, which is equivalent to the energy fixed during photosynthesis.

**Net Primary Production** measures the amount of biomass accumulated by the plant and is measured as gross primary production minus the energy the plant loses through respiration.Net Primary Production is measured as the weight of living plant material, including leaves, stems and roots.

**Productivity:** The rate of biomass production. [Unit: g –2 yr –1 or (kcal m – 2 ) yr –1]

**Gross primary productivity (GPP):** The rate of production of organic matter during photosynthesis.

**Net primary productivity (NPP):** Gross primary productivity minus respiration losses (R).

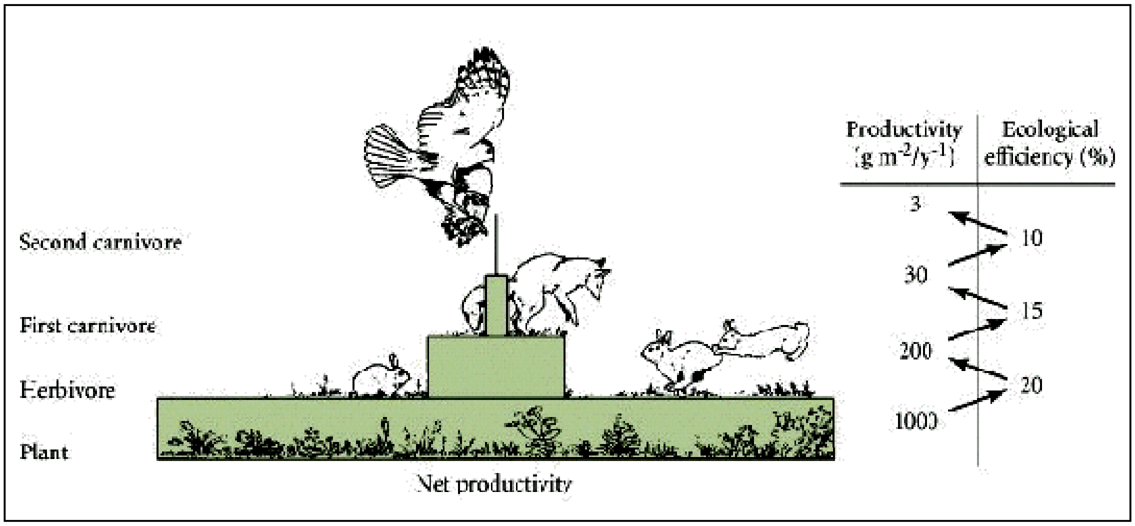
$$GPP - R = NPP$$

**Secondary productivity:** The rate of formation of new organic matter by consumers. Primary productivity depends upon-

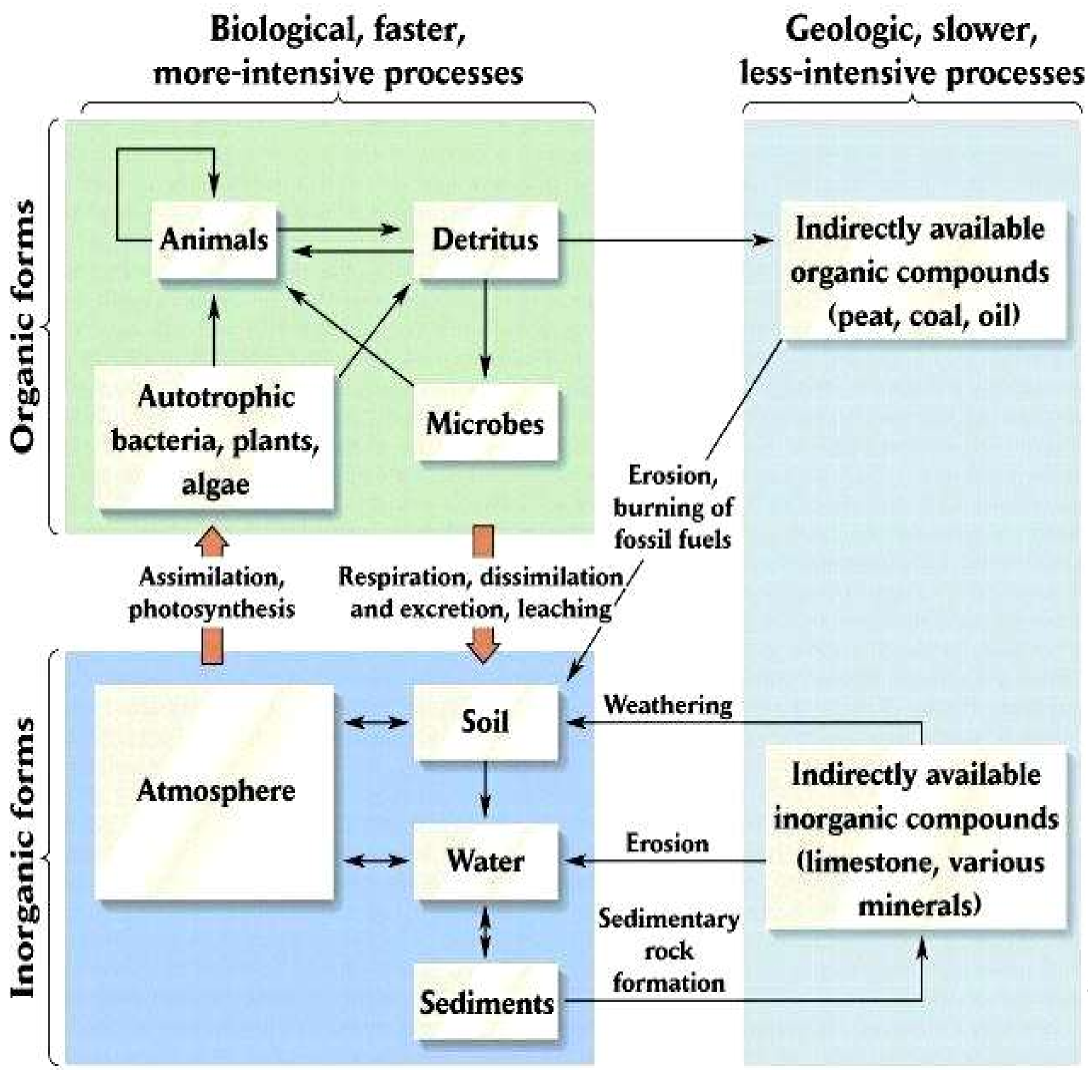
- type of plant species inhabiting a particular area
- photosynthetic capacity of plants
- nutrient availability

**Patterns in Primary Production:**

- With each link in a food chain, a great deal of energy is dissipated before it can be consumed by organisms feeding at the next higher trophiclevel.
- As Lindeman (1942) pointed –the amount of energy reaching each trophic level depends on the netprimary production at the base of the food chain and the efficiencies with which animals convert food energy into their own biomass energy through growth and reproduction at each higher trophiclevel.
- Of the light energy assimilated by photosynthesis, plants use between 15 to 70% for their own maintenance, thereby making thisportion unavailable to the consumers.
- Herbivores and carnivores are more active than plants and expend correspondingly more of their assimilated energy on maintenance.
- As a result, the productivity of each trophic level is typically only 5-20% that of the level below it.
- This percentage of energy transferred from one trophic level to the next is called ecological efficiency or food chain efficiency between two trophic levels.




**Pathways of Elements in the Ecosystem –a generalization**



**Energy Flow in an Ecosystem:**

Energy has been defined as the capacity to do work. Energy exists in two forms potential and kinetic. Potential energy is the energy at rest {i.e., stored energy) capable of performing work. Kinetic energyis the energy of motion (free energy).

It results in work performance at the expense of potential energy. Conversion of potential energy intokinetic energy involves the imparting of motion.

The source of energy required by all living organisms is the chemical energy of their food. Thechemical energy is obtained by the conversion of the radiant energy of sun.

The radiant energy is in the form of electromagnetic waves which are released from the sun during the transmutation of hydrogen to helium. The chemical energy stored in the food of living organisms is converted into potential energy by the arrangement of the constituent atoms of food in a particular manner. In any ecosystem there should be unidirectional flow of energy.

This energy flow is based on two important Laws of Thermodynamics which are as follows:

1. **The first law of Thermodynamics:**

It states that the amount of energy in the universe is constant. It may change from one form to another,but it can neither be created nor destroyed. Light energy can be neither created nor destroyed as it passes through the atmosphere. It may, however, be transformed into another type of energy, such as chemical energy or heat energy. These forms of energy cannot be transformed into electromagnetic radiation.

2. **The second law of Thermodynamics:**

It states that non-random energy (mechanical, chemical, radiant energy) cannot be changed without some degradation into heat energy. The change of energy from one form to another takes place in such a way that a part of energy assumes waste form (heat energy). In this way, after transformation the capacity of energy to perform work is decreased. Thus, energy flows from higher to lower level.

Main source of energy is sun. Approximately 57% of sun energy is absorbed in the atmosphere and scattered in the space. Some 35% is spent to heat water and land areas and to evaporate water. Of the approximately 8% of light energy striking plant surface, 10% to 15% is reflected, 5% is transmitted and 80 to 85% is absorbed; and an average of only 2% (0.5 to 3.5%) of the total light energy striking on a leaf is used in photosynthesis and rest is transformed into heat energy.

**Energy flow in Ecosystems:**

Living organisms can use energy in two forms radiant and fixed energy. Radiant energy is in the form of electromagnetic waves, such as light. Fixed energy is potential chemical energy bound in various organic substances which can be broken down in order to release their energy content. Organisms that can fix radiant energy utilizing inorganic substances to produce organic molecules are called autotrophs. Organisms that cannot obtain energy from abiotic source but depend on energy-rich organic molecules synthesized by autotrophs are called heterotrophs. Those which obtain energy from living organisms are called consumers and those which obtain energy from dead organisms are called decomposers.

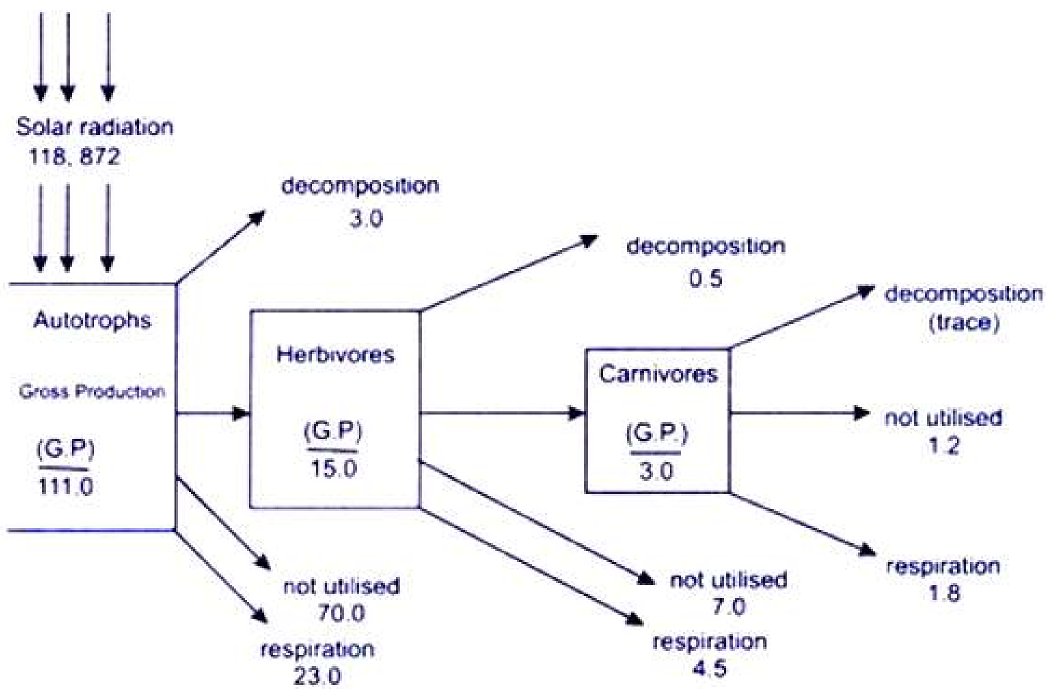



**Fig. 1.3** Energy flow diagram for a lake (freshwater ecosystem) in g cal/cm2/yr

**Flow of Energy at different Levels of Ecosystem:**

When the light energy falls on the green surfaces of plants, a part of it is transformed into chemical energy which is stored in various organic products in the plants. When the herbivores consume plants as food and convert chemical energy accumulated in plant products into kinetic energy, degradation of energy will occur through its conversion into heat. When herbivores are consumed by carnivores of the first order (secondary consumers) further degradation will occur. Similarly, when primary carnivores are consumed by top carnivores, again energy will be degraded.

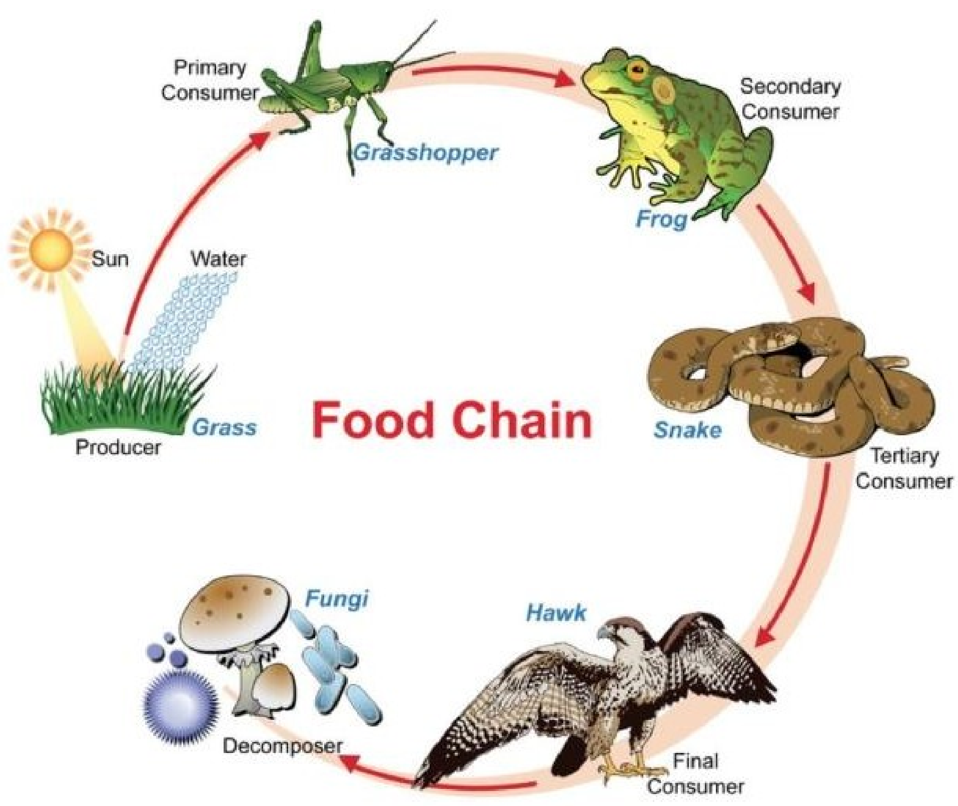
**Food chain:**

A food chain may be defined as the transfer of energy and nutrients from the source in plants througha series of organisms with repeated processes of eating and being eaten. For example, the marsh vegetation is eaten by the grasshopper the grasshopper is consumed by shrew, the shrew by the marsh hawk or owl.

Thus, a relationship is established:

Marsh grass → Grass hopper → Shrew → Marsh hawk

It is estimated that only about 10 per cent of the potential energy available at the previous trophic level is being available to an organism. The efficiency of a food chain is, therefore, dependent on the number of trophic levels or links in a food chain. The shorter the food chain, the more is the amount of energy available to the last trophic levels in an eco-system.



In all the eco-systems, energy moves as per the direction given below:

Sun → Producer → Consumer → DecomposerSun → Autotroph → Heterotroph.

Food chains are of three types:

1) Grazing or Predator food chain.
2) Parasitic food chain.
3) Saprophytic or detritus food chain.

***1) Grazing or Pasturing Food Chain:***

This food chain starts from green plants (producers), passes through the herbivore (primaryconsumers) and ends with carnivore (secondary or tertiary consumers).

The total energy assimilated by green plants is subjected to three important processes:

(i) It may be oxidised in respiration.

(ii) It may die and decay.

(iii) It may be eaten by herbivorous animals.

Like green plants, the disposition of energy in herbivores takes place by either respiration or decay of organic matter by microbes or consumption by carnivore. The primary carnivores eat herbivore and secondary carnivore eat primary carnivore. The total energy in herbivores takes by decay of organic matter by microbes the primary carnivore eat herbivore eat primary carnivore.

The total energy assimilated by primary carnivore is derived entirely from the herbivore and its disposition in to respiration, decay and further consumption by other carnivore is entirely similar to that of herbivore. Thus, the grazing food chain is more effective or efficient as most of the primary production is passed on through different trophic levels and only a small fraction goes to the decomposer system.

A grazing food chain can be described in terms of trophic levels as shown below: Autotroph→ Herbivore→ Primary Carnivore →Secondary

Carnivore→ Tertiary Carnivore → Decomposer etc.

***2) Parasitic rood chain:***

This food chain starts from herbivore but food energy passes from larger to smaller organism without outright killing as in case of predator. Hence, the larger animals are considered to be the hosts and the smaller animals which fulfill their nutritional requirements from the hosts are considered as parasites.

***3) Saprophytic or Detritus Food chain:***

In this food chain, the dead organic matter or organic wastes (metabolic wastes and extrudates) of eco-system go to the micro-organisms and finally to detritus feeding organiss known as detrivore. Theenergy stored in detritus serves as a source of energy for detrivore. This type of food chain is less efficient as the major portion of energy is lost to the eco-system without being properly used.

Food Chain of Different Eco-Systems:

**Grassland eco system:**

Grass →Grasshopper →Toad→ Snake

Grass→ Rat→ Snake→ Hawk

Grass→ Goat→ Man→ Tiger

**Forest eco-system:**

Plant→ Deer→ Lion

Plant→ Deer→ Tiger

Plant→ Goat→ Tiger

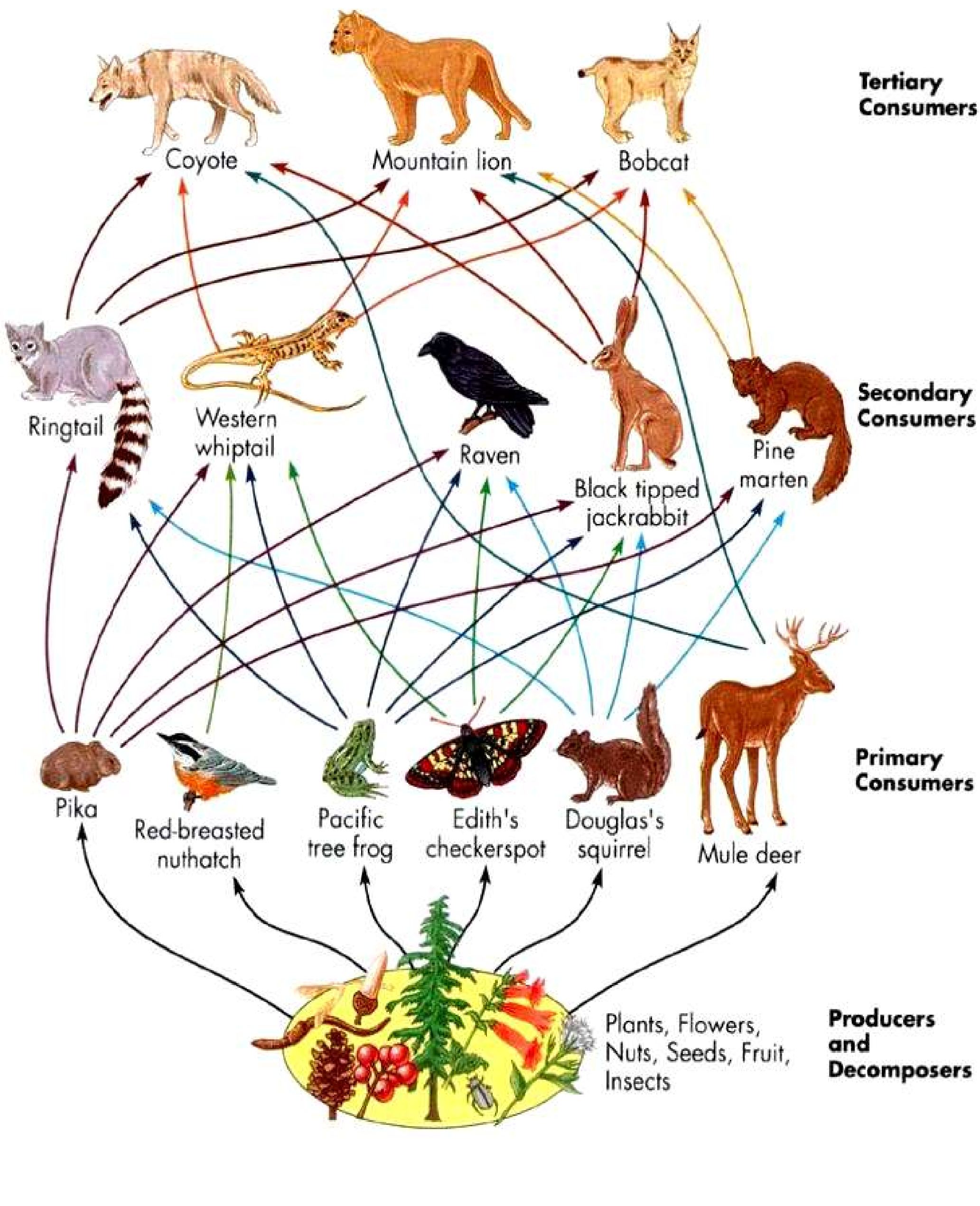
**Pond eco-system:**

Phytoplankton→ Zooplanktons→ Small fish→ Big fish

**Food Web:**

Food chains are not always simple and isolated but are interconnected with one another. The interlocking pattern of food chains or a matrix of food chains, with all sorts of short circuits and connections is often called the food web or food net. However, in any food web all the species not equally important and many could be removed without seriously affecting the more important species.

Thus, food web is a simplified representation of the complex interrelationships of the population of plants and animals which exist in a community. The basic operational principle in a food web is that each species is dependent upon at least one other species, and the numbers of each link species must be sufficient for their continued existence. If these conditions are maintained, the web will exist in an ecological nutritional equilibrium.



**Ecological pyramid:**

Ecological pyramids are the graphic representations of trophic levels in an ecosystem. They are pyramidal in shape and they are of three types: The producers make the base of the pyramid and the subsequent tiers of the pyramid represent herbivore, carnivore and top carnivore levels.

1. **Pyramid of number:** This represents the number of organisms at each trophic level. For example in a grassland the number of grasses is more than the number of herbivores that feed on them and the number of herbivores is more than the number of carnivores. In some instances the pyramid of number may be inverted, i.e herbivores are more than primary producers as you may observe that many caterpillars and insects feed on a single tree.
2. **Pyramid of biomass:** This represents the total standing crop biomass at each trophic level. Standing crop biomass is the amount of the living matter at any given time. It is expressed as gm/unit area or kilo cal/unit area. In most of the terrestrial ecosystems the pyramid of biomass is upright. However, in case of aquatic ecosystems the pyramid of biomass may be inverted e.g. in a pond phytoplankton are the main producers, they have very short life cycles and a rapid turn over rate (i.e. they are rapidly replaced by new plants). Therefore, their total biomass at any given time is less than the biomass of herbivores supported by them.
3. **Pyramid of energy:** This pyramid represents the total amount of energy at each trophic level. Energy is expressed in terms of rate such as kcal/unit area /unit time or cal/unit area/unit time.eg. in a lake autotroph energy is 20810 kcal/m/year. Energy pyramids are never inverted.

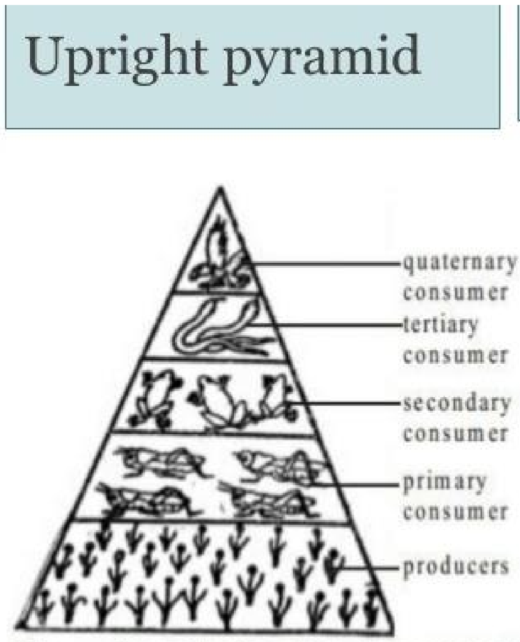
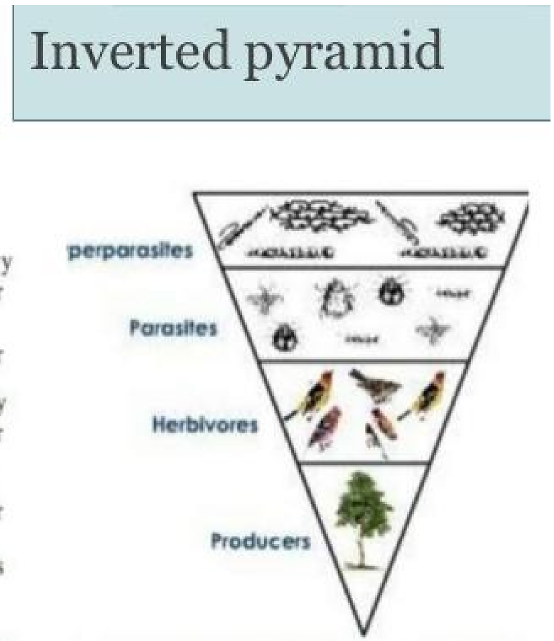



Fig. Pyramid of numbers in a grassland




Inverted pyramid of number

**Quantifying energy flow:**

To quantify the flux of energy through the ecosystem it is necessary to determine the processes involve and quantify them. The processes include – consumption, ingestion, assimilation, respiration and production**. Ecological Efficiency** is a product of **Consumption efficiency**, **Assimilation efficiency** and the **Production Efficiency**.

Of the food ingested by a consumer (I), a portion isassimilated across the gut wall (A), and the remainder isexpelled as waste (W). Of the energy that is assimilated some is used in respiration (R) and the remainder goes into production (P), which includes growth and reproduction. The ratio of assimilation to ingestion (A/I) is called assimilation efficiency. It is a measure of the efficiency with which the consumer extractsenergy from its food.

**Food Chains–Quantifying energy flow:**

- The ratio of production to assimilation (P/A) is called **production efficiency**. It is a measure of the efficiency with which the consumer incorporates assimilated energy into secondary production.

- The energy available to a given trophic level (n) is the production of the next lower level (n - 1).

- The **consumption efficiency** is the ratio of ingestion to production (In/Pn-1), it defines the amount of available energy being consumed.
- Application of efficiency values for each trophic level gives an estimate of the flow of energy through the whole ecosystem.

**TABLE 10-3 Definitions of several energetic efficiencies**

$$\text{Exploitation efficiency} = \frac{\text{Ingestion of food}}{\text{Prey production}}$$

$$\text{Assimilation efficiency} = \frac{\text{Assimilation}}{\text{Ingestion}}$$

$$\text{Net production efficiency} = \frac{\text{Production (growth and reproduction)}}{\text{Assimilation}}$$

$$\text{Gross production efficiency} = \text{Assimilation efficiency} \times \text{Net production efficiency} = \frac{\text{Production}}{\text{Ingestion}}$$

$$\text{Ecological efficiency} = \text{Exploitation efficiency} \times \text{Assimilation efficiency} \times \text{Net production efficiency} = \frac{\text{Consumer production}}{\text{Prey production}}$$

**Disturbance (natural and anthropogenic) and their impact on plant ecology**

- Ecological disturbance is an event or force, of abiotic or biotic origin, that brings about either mortality of organisms or changes in their spatial patterning in the ecosystems they inhabit.
- It is a relatively discrete event such as fire, windstorm, flood, extremely

cold temperature, drought or epidemic that disrupts an ecosystem by influencing community structure & function.

- Disturbance plays a significant role in shaping the structure of individual populations and the character of whole ecosystems.
- Disturbances, both create and are influenced by patterns on the landscape

**Characteristics of Disturbance:**

Disturbances have spatial and temporal characteristics:

- Small-scale disturbances make gaps in the substrate or vegetation, creating patches of different composition or succession stages.
  - Large-scale disturbances favor opportunistic species.
  - Severe disturbances can replace a community altogether from an ecosystem.
- Frequent disturbances can eliminate certain species from the ecosystem.
- Disturbance Regime -Disturbance regime of a vegetation system is the sum of all disturbances affecting the system. It can be characterized by several parameters:

| | | |
|---|---|---|
| **1.** | Kind | Kind refers to the type of disturbances, which vary with climate, topography, substrate and biota. |
| **2.** | Spatial parameters | Spatial parameters are the area, shape & spatial distribution of patches created by disturbances |
| **3.** | Temporal parameters | Temporal parameters are the frequency, return interval, cycle, and rotation period of disturbances. |
| **4.** | Specificity | Specificity is correlation between a type of disturbance & specific characteristics of disturbed sites, such as species, size class, seral stage and location. |
| **5.** | Magnitude | Magnitude includes the intensity (the physical force per event per area per time) and severity (the impact |

| | | |
|---|---|---|
| | | on organisms and ecosystem structure and composition) of disturbances, and generates patch variations, internal heterogeneity and biological legacies |
| **6.** | Synergism | Synergisms are the interactions amongdifferent kinds of disturbances. |

**Invasive Plant Species:**

Species have been and are being introduced to regions outside their historic (post-glacial) nativerange.

Species are being transported to new locations at up to 10,000 timesgreater rate than by naturaldispersal.

Such species are also called: exotic species, non- indigenousspecies, non-native species, introduced species, colonizingspecies.

There is a general agreement now to the term 'invasive alien species', meaning non-native speciesintroduced to new areas where they are found to cause problems.

Species that are rapidly expanding outside their native range.Usually exotics far from their native habitats, often other continents. In most cases they have not dispersed naturally, but have been brought either purposefully or in advertently to a new habitat. Large proportion of the plants that have become seriously invasive were deliberately introduced, planted and cultivated by people. Species invasions affect plant communities in two ways: Through the effects of the spread of non-native plants on native plant species, communities and ecosystems. Through the effects of invasive insect herbivores and pathogens on native plant species. A plant becomes potentially invasive when it is capable of

i. Reproduction at younger ages
ii. Has smaller seeds
iii. Produces large seed crops at shorter interval

**What influences success of invasion?**

Species Characteristics

- high fecundity
- small body size
- vegetative or asexual reproduction
- high genetic diversity
- high phenotypic plasticity
- broad native range
- abundant in native range
- physiological tolerance
- habitat generalist
- human commensal
- loss of natural enemies
- invasional meltdown

**Generalizations Regarding Habitat Invasibility:**

- climatically matched
- disturbed
- low diversity
- absence of predators
- presence of vacant niches
- low connectance of food web
- nutrient rich (plants)

**Vulnerability of Communities to Invasions:**

- ✓ Some communities are vulnerable to invasions while others can resist invasions.
- ✓ Invaders are most likely to become established in disturbed and species-poor communities.
- ✓ Disturbance may be a critical factor in promoting invasions but there exist many conflicting evidences against uniformity in its role: since it includes more than a single factor like changes in resource availability, competitive

interactions, microclimates, predator-prey relationships.

- ✓ Invasive species usually grow vigorously beyond their own native ranges, an explanation being that the new range is devoid of its natural enemies(competitors, predatorsand pathogens).
- ✓ Variations in resource availability has also been proposed to be an underlying cause for positive interactions between native and invasive species **diversity.**

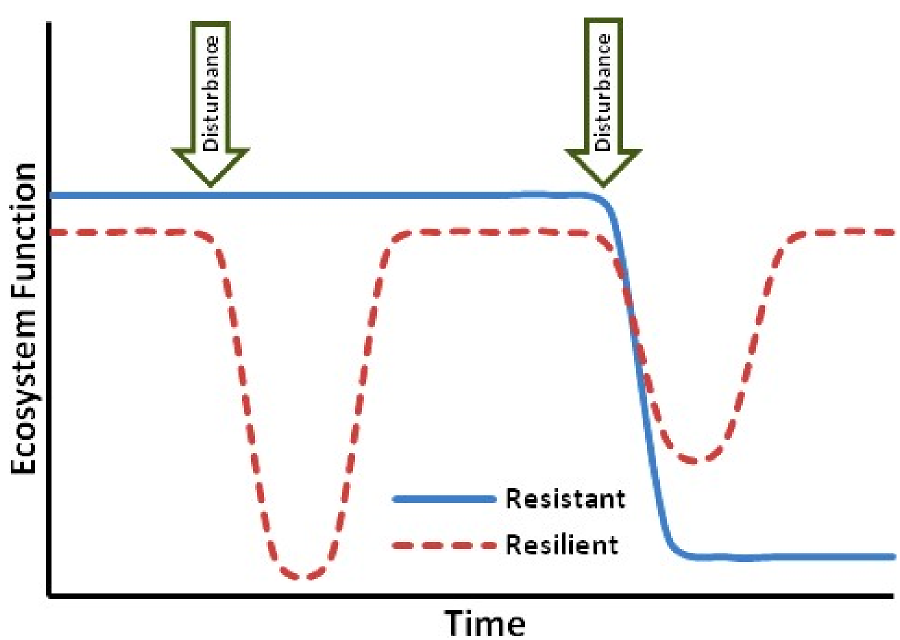
**Resistance and Resilience of EcosystemsResistant system:**

The black spruce forest of Alaska burns easily in the summer. Afterwards there is a secondary succession. There are immediate physical changes. The blackened soil, without its insulating layers of moss and litter, warms up and the permafrost retreats. Nutrients in previously frozen areas are now available. Black spruce growsfrom seed, but slowly. In the meantime, windblown birch and poplar establish and thrive in the nutrient-rich, warmer soil. Slowly, spruce and moss grow and the litter layer redevelops. The soil becomes colder again and once thebirch and poplar die they are not replaced.

Moss and spruce litter decompose very slowly. The litter layer thickens; thepermafrost rises and nutrients become bound in the un- decomposed material.

**Resilient system:**

The taiga therefore has low resistance to fire: it burns easily. But the original system is soon restored after the fire. It recovers, it has high resilience. Although, it is resilient in the face of fire, taiga is however not resilient to any other kind of disturbance. If the spruce trees were felled and removed, there would be no cones from which new seeds could establish. The spruce forest might then never recover.



- Rain forest doesnot burn easily, because it doesn't dry out as the taiga does in summer. It is therefore resistant to fire, and the only large-scale firesare those caused by humans. However, once burned, it showslow resilience, particularly if burned on slopes, where nutrient leaching is much faster than on level ground. Low resilience means that theoriginal system may never recover.The extent of resistance and resilience therefore depends on both the natureof the ecosystem, and the type of disturbance.
- Ecosystems that show a high degree of stability may have different combinationsof resistance and resilience.
- Research has shown that species diversity is often the key to both ecosystem resistance and resilience.An ecosystem rich in biodiversity will likely be more stable than one whose biodiversity is low.
- Changing environmental conditionscan cause the decline of local biodiversity. If this happens, an ecosystem’s resistance and/or resilience may decline. The end result isthat the ecosystem loses stability.
- Ecosystems that are less stable may not be able to respond to a normal environmental disturbance, which may damage ecosystem structure, ecosystem function, or both.

## 11. Biogeography: biogeographic patterns; biomes; major biogeographical regions of India.

**Biogeography:** It is the study of the distribution of species on Earth in the past and present, and how the distribution is effected by abiotic factors such as habitat, climate and terrain. The field is divided into three disciplines of biogeography: historical, ecological and conservation.

Historical biogeography is also called paleobiogeography and studies species distribution now as it relates to distribution in the past. Ecological biogeography examines the distribution of species in relation to biotic and abiotic factors in the environment. Finally, conservation biogeography is a relatively new field of biogeography which combines the study of conservation with biogeography to try and anticipate future conditions so that planning can be done to protect the biodiversity on Earth.

**Biogeographic patterns:**

Biogeographic patterns result from environmental influences interacting with historic legacies and biotic characteristics. The emergence of biogeographic patterns is often scale dependent and the identification of causal processes is difficult due to complex cross-scale interactions.

**Biome:**

Biome refers to the community of plants and animals that occur naturally in an area, often sharing common characteristics specific to that area.

There are **five major types of biomes: aquatic**, **grassland**, **forest**, **desert**, **and tundra**, though, some of the above biomes can be further subdivided into more specific categories, such as freshwater, marine, savanna, tropical rainforest, temperate rainforest, and taiga.

**Aquatic biomes:** It includes both freshwater and marine biomes. Freshwater biomes are bodies of water surrounded by land—such as ponds, rivers, and lakes—that have a salt content of less than one percent. Marine biomes cover close to three-quarters of Earth's surface. Marine biomes include the ocean, coral reefs, and estuaries.

**Grassland:** These are open regions that are dominated by grass and have a warm, dry climate. There are two types of grasslands: tropical grasslands (sometimes called savannas) and temperate grasslands. Savannas are found closer to the equator and can have a few scattered trees. They cover almost half of the continent of Africa, as well as areas of Australia, India, and South America. Temperate grasslands are found further away from the equator, in South Africa, Hungary, Argentina, Uruguay, North America, and Russia. They do not have any trees or shrubs, and receive less precipitation than savannas. Prairies and steppes are two types of temperate grasslands; prairies are characterized as having taller grasses, while steppes have shorter grasses.

**Forests:** They are dominated by trees, and cover about one-third of the Earth. Forests contain much of the world's terrestrial biodiversity, including insects, birds, and mammals. The three major forest biomes are temperate forests, tropical forests, and boreal forests (also known as the taiga). These forest types occur at different latitudes, and therefore experience different climatic conditions. Tropical forests are warm, humid, and found close to the equator. Temperate forests are found at higher latitudes and experience all four seasons. Boreal forests are found at even higher latitudes, and have the coldest and driest climate, where precipitation occurs primarily in the form of snow.

**Deserts:** These are dry areas where rainfall is less than 50 centimeters (20 inches) per year. They cover around 20 percent of Earth's surface. Deserts can be either cold or hot, although most of them are found in subtropical areas. Because of their extreme conditions, there is not as much biodiversity found in deserts as in other biomes. Any vegetation and wildlife living in a desert must have special adaptations for surviving in a dry environment. Desert wildlife consists primarily of reptiles and small mammals.

Deserts can fall into four categories according to their geographic location or climatic conditions: hot and dry, semiarid, coastal, and cold.

**Tundra:** A tundra has extremely inhospitable conditions, with the lowest measured temperatures of any of the five major biomes with average yearly temperatures ranging from -34 to 12 degrees Celsius (-29 to 54 degrees Fahrenheit). They also have a low amount of precipitation, just 15–25 centimeters (six to ten inches) per year, as well as poor quality soil nutrients and short summers. There are two types of tundra: arctic and alpine. The tundra does not have much biodiversity and vegetation is simple, including shrubs, grasses, mosses, and lichens. This is partly due to a frozen layer under the soil surface, called permafrost. The arctic tundra is found north of boreal forests and the alpine tundra is found on mountains where the altitude is too high for trees to survive. Any wildlife inhabiting the tundra must be adapted to its extreme conditions to survive.

**Major Biogeographical Zones of India:**

Biogeography is the study of the distribution of species and ecosystems in geographic spaceand through geological time. Organisms and biological communities often vary in a regular fashion along geographic gradients of latitude, elevation, isolation and habitat area.

Phytogeography is the branch of biogeography that studies the distribution of plants.

Biogeographic classification of India is the division of India according to biogeographic characteristics. Biogeography is the study of the distribution of species (biology), organisms, and ecosystems in geographic space and through geological time. There are ten biogeographic zones in India.

| Sl. No. | Bio-geographiczones | Biotic province |
|---|---|---|
| 1 | Trans-Himalaya | Ladakh mountains, Tibetan Plataeu |

| | | |
|---|---|---|
| 2 | Himalaya | North-West, West, Central & East Himalayas |
| 3 | Desert | Thar, Kutch |
| 4 | Semi-arid | Punjab plains, Gujarat Rajputana |
| 5 | Western Ghats | Malabar plains, Western Ghats |
| 6 | Deccan Peninsula | Central Highlands, Chotta Nagpur, Eastern Highlands, Central Plateau, Deccan South |
| 7 | Gangetic Plains | Upper & Lower Gangetic Plains |
| 8 | Coast | West & East Coast, Lakshadweep |
| 9 | North-East | Brahmaputra Valley, North East Hills |
| 10 | Islands | Andaman & Nicobar Islands |

**1. The Trans-Himalayan Region:**

The Himalayan ranges immediately north of the Great Himalayan range are called the Trans- Himalayas. This area is very cold and arid (4,500 Œ 6,000 mts. above msl). The Trans-Himalayan region with its sparse vegetation has the richest wild sheep and goat community in the world. The snow leopard is found here, as is the migratory black-necked crane.The only vegetation is a sparse alpine steppe. Extensive areas consist of bare rock and glaciers.

**2. The Himalayan Region:**

The extremely high altitude gradient results in the tremendous biodiversity of the Himalayan region. Flora and fauna vary according to both altitude and climatic conditions: tropical rainforests in the Eastern Himalayas and dense subtropical and alpine forests in the Central and Western Himalayas. The forests are very dense with extensive growth of grass and evergreen tall trees. Oak, chestnut, conifer, ash, pine, deodar are abundant in Himalayas. There is no vegetation above the snowline. Several interesting animals live in the Himalayan ranges. Chief species include wild sheep, mountain goats, ibex, shrew, and tapir. Panda and snow leopard are also found here. The lower levels of the mountain range support many types of orchids. On the eastern slopes, rhododendrons grow to tree height.

**3. The Indian Desert:**

The natural vegetation consists of tropical thorn forests and tropical dry deciduous forests, sandy deserts with seasonal salt marshes are found in the Kutch region. Typical shrubs are found growing onsand dunes. Sewan grass covers extensive areas.

**4. The Semi-Arid Region:**

The semi-arid region in the west of India includes the arid desert areas of Thar and Rajasthan extending to the Gulf of Kutch and Cambay and the whole Kathiawar peninsula. The natural vegetation consists of tropical thorn forests and tropical dry deciduous forests, moisture forests (extreme north) and also mangroves. Thorny shrubs, grasses and some bamboos are present in some regions. The sandy plains have a few scattered trees of *Acacia* and *Prosopis*. A few species of xerophytic herbs and some ephemeral herbs are found in this semi-arid tract. Birds, jackals, leopards, eagles, snakes, fox, buffaloes are found in this region.The rocky habitats are covered by bushes of Euphorbia while species of Salvadora and Tamarix occur mainly near saline depressions.

**5. The Western Ghats:**

The mountains along the west coast of peninsular India are the Western Ghats, which constitute one of the unique biological regions of the world. The Western Ghats extend from the southern tip of the peninsula (8°N) northwards about 1600 km to the mouth of the river Tapti (21°N).They cover only 5% of India's land surface but are home to more than about 4,000 of the country's plant species of which 1800 are endemic. The monsoon forests occur both on western margins of the ghats and on the eastern side where there is less rainfall. This zone displays diversity of forests from evergreen to dry deciduous.

The mountains rise to average altitudes between 900 and 1500 m above sea level, intercepting monsoon winds from the southwest and creating a rain shadow in the region to their East.

The varied climate and diverse topography create a wide array of habitats that support unique sets of plant and animal species. Apart from biological diversity, the region boasts of high levels of cultural diversity, as many indigenous people inhabit its forests.

The Western Ghats are amongst the 25 biodiversity hot-spots recognized globally. These hills are known for their high levels of endemism expressed at both higher and lower taxonomic levels. Most of the Western Ghat endemic plants are associated with evergreen forests.

The region also shares several plant species with Sri Lanka. The higher altitude forests were, if at all, sparsely populated with tribal people. Rice cultivation in the fertile valley proceeded gardens of early commercial crops like areca nut and pepper. The original vegetation of the ill-drained valley bottoms with sluggish streams in elevations below 100m would be often a special formation, the Myristica swamp.

Expansion of traditional agriculture and the spread of particularly rubber, tea, coffee and forest tree plantations would have wiped out large pockets of primary forests in valleys. The Western Ghats are well known for harboring 14 endemic species of caecilians (i.e., legless amphibians) out of 15 recorded from the region so far.

**6. The Deccan Peninsula:**

The Deccan Peninsula is a large area of raised land covering about 43% of India's total land surface. Itis bound by the Satpura range on the north, Western Ghats on the west and Eastern Ghats on the east. The elevation of the plateau varies from 900 mts. in the west to 300 mts. in the east. There are four major rivers that support the wetlands of this region which have fertile black and red soil. Large parts are covered by tropical forests. Tropical dry deciduous forests occur in northern, central & southern part of the plateau. The eastern part of the plateau in Andhra Pradesh, Madhya Pradesh & Orissa have moist deciduous forests.

**7. The Gangetic Plain:**

The Gangetic plain is one of India's most fertile regions. The soil of this region is formed by the alluvial deposits of the Ganges and its tributaries. The Gangetic plains stretching from western Uttar Pradesh to Bihar & West Bengal are mostly under agriculture. The large forest area is under tropical dry deciduous forest and the southeastern end of the Gangetic plain merges with the littoral and mangroves regions of the Sunderbans.

Topographic uniformity, except in the arid Western Rajasthan is a common feature throughout these plains. The plain supports some of the highest population densities depending upon purely agro-based economy in some of these areas. The trees belonging to these forests are teak, sal, shisham, mahua, khair etc.

**8. The Coastal Region:**

India has a coastline extending over 7,516. 4 km. The Indian coasts vary in their characteristics and structures. The west coast is narrow except around the Gulf of Cambay and the Gulf of Kutch. In the extreme south, however, it is somewhat wider along the south Sahyadri.

The backwaters are the characteristic features of this coast. The east coast plains, in contrast are broader due to depositional activities of the east-flowing rivers owing to the change in their base levels.

Extensive deltas of the, Godavari, Krishna and Kaveri are the characteristic features of this coast. Mangrove vegetation is characteristic of estuarine tracts along the coast for instance, at Ratnagiri in Maharashtra.

Larger parts of the coastal plains are covered by fertile soils on which different crops are grown. Rice is the main crop of these areas. Coconut trees grow all along the coast.

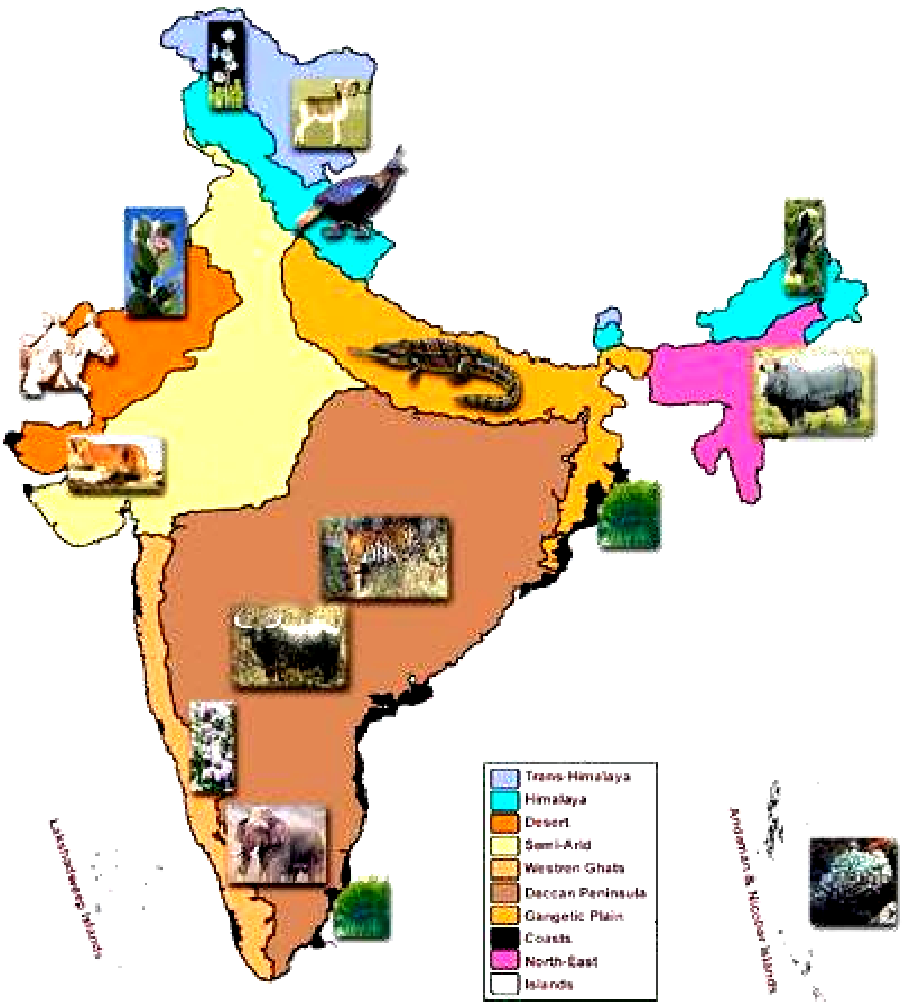
Coconut and rubber are the main vegetation of coastal area. The main states of coastal areas are Gujarat, Maharashtra, Goa, Karnataka, Kerala, West Bengal, Odisha, Andra pradesh, Tamil nadu and Puducherry. Animal species include dugong, dolphins, crocodiles and avifauna

**9. The North-East:**

Biological resources are rich in this zone. The tropical vegetation of the northeast is rich in evergreen & semi-evergreen rain forests, moist deciduous monsoon forests, swamps and grasslands.

**10. The Indian Islands:**

It is a group of 325 islands: Andaman to the north and Nicobar to the south. Rainfall is heavy, with both Northeast and Southwest monsoons. Many unique plants and animals are found here. About 2,200 species of angiosperms are found here of which 200 are endemic. The Andaman & Nicobar Islands have tropical evergreen forests and tropical semi-evergreen forests as well as moist deciduous forests, littoral and mangrove forests.




## 12. Environmental Economics: Introduction; valuation; sustainable development.

**Environmental Economics:**

Environmental economics is the study of the cost-effective allocation, use, and protection of the world's natural resources.

- Environmental economics studies the impact of environmental policies and devises solutions to problems resulting from them.
- Environmental economics can either be prescriptive-based or incentive-based.
- A major subject of environmental economics is externalities; the additional costs of doing business that are not paid by the business or its consumers.
- Another major subject of environmental economics is placing a value on public goods, such as clean air, and calculating the costs of losing those goods.
- Since some environmental goods are not limited to a single country, environmental economics often requires a transnational approach.

The basic theory underpinning environmental economics is that environmental amenities (or environmental goods) have economic value and there are costs to economic growth that are not accounted for in more traditional models.

Environmental goods include things like access to clean water, clean air, the survival of wildlife, and the general climate. Although it is hard to put a price tag on environmental goods, there may be a high cost when they are lost.

**What Is the Difference Between Environmental Economics and Ecological Economics?**

Environmental and ecological economics are both sub-fields of economic thought that study the interactions between human activity and the natural environment. The difference is that environmental economics studies the relationship between the environment and the economy, while ecological economics considers the economy to be a subsystem of the wider ecosystem.

**Valuation:**

Assessing the economic value of the environment is a major topic within the field. The values of natural resources often are not reflected in prices that markets set and, in fact, many of them are available at no monetary charge. This mismatch frequently causes distortions in pricing of natural assets: both overuse of them and underinvestment in them. Economic value or tangible benefits of ecosystem services and, more generally, of natural resources, include both use and indirect. Non-use values include existence, option, and bequest values. For example, some people may value the existence of a diverse set of species, regardless of the effect of the loss of a species on ecosystem services. The existence of these species may have an option value, as there may be the possibility of using it for some human purpose. For example, certain plants may be researched for drugs. Individuals may value the ability to leave a pristine environment for their children.

Use and indirect use values can often be inferred from revealed behavior, such as the cost of taking recreational trips or using hedonic methods in which values are estimated based on observed prices. Non-use values are usually estimated using stated preference methods such as contingent valuation or choice modelling. Contingent valuation typically takes the form of surveys in which people are asked how much they would pay to observe and recreate in the environment (willingness to pay) or their willingness to accept (WTA) compensation for the destruction of the environmental good. Hedonic pricing examines the effect the environment has on economic decisions through housing prices, traveling expenses, and payments to visit parks.

Economists value the environment placing a monetary value on the basis of perceived ‘goods‘ and ’bads‘ arising from changes in environmental quality or resource availability. The rationale for the economic valuation of natural resources is that they somehow impact on the utility (or well-being) of individuals, and that these individuals can identify a satisfactory trade-off between quantities of money and the environmental goods and bads they want. The objective is to find ways to measure the wide range of effects of environmental change on a single monetary scale. Money is used as the measuring stick to evaluate, although imperfectly, the extent to which individual utility is affected. This approach necessitates applying a monetary value to goods that do not have a market value, in an attempt to extend the utilitarian principle of the free market into environmental decision-making. The economic valuation approach makes several important assumptions, including commensurability of values, and assumes a compensatory approach in the evaluation of environmental changes, corresponding to a weak sustainability approach.

The total economic value (TEV) of a resource indicates the total value of the resource in so far as it affects human welfare and integrates two broad categories of values: use values, associated with the direct contact with the natural resource in some way, and non-use values, corresponding to the value derived from a resource, either directly or indirectly, but that does not depend on the use of that resource. A full taxonomy of such economic values can be found in any economic valuation handbook, including values categories such as option value, bequest value and existence value.

**Sustainable development:**

The World Commission on Environment and Development (the Brundtland Commission) in its report to the United Nations in 1987 defined sustainable development as meeting the needs of the present without compromising the ability of future generation to meet their own needs.

Agenda 21, adopted during the United Nations Conference on Environment and Development (UNCED) called Earth Summit held in Rio de Janeiro in Brazil in 1992 is a blue print on how to make development socially, economically and environmentally sustainable.

**Principles of Sustainable Development:**

The Rio Declaration on Environment and Development fleshes out the definition by listing 18 principles of sustainability, viz –

1. People are entitled to a healthy and productive life in harmony with nature.
2. Development today must not undermine the development and environment needs of present and future generations.

**3.** Nations have the sovereign right to exploit their own resources but without causing environmental damage beyond their borders.

**4.** Nations shall develop international laws to provide compensation for damage that activities under their control cause to areas beyond their borders.

**5.** Nations shall use the precautionary approach to protect the environment. Where there are threats of serious or irreversible damage, scientific uncertainty shall not be used to postpone cost-effective measures to prevent environmental degradation.

**6.** In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.

**7.** Eradicating poverty and reducing disparities in living standards in different parts of the world are essential to achieve sustainable development and to meet the needs of the majority of people.

**8.** Nations shall cooperate to conserve, protect and restore the health and integrity of the Earth’s ecosystem. The developed countries acknowledge the responsibility of sustainable development.

**9.** Nations should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies.

**10.** Environmental issues are best handled with the participation of all concerned citizens. Nations shall facilitate and encourage public awareness and participation by making environmental information widely available.

**11.** Nations shall enact effective environmental laws and develop national law regarding liability for the victims of pollution and other environmental damages. Where they have authority, nations shall assess the environmental impact of proposed activities that are likely to have a significant adverse impact.

**12.** Nations should cooperate to promote an open international economic system that will lead to economic growth and sustainable development in all countries. Environmental policies should not be used as an unjustifiable means of restricting international trade.

13. The polluter should, in principle, bear the cost of pollution.
14. Nations shall warn one another of natural disasters or activities that may have harmful transboundary impacts.
15. Sustainable development requires better scientific understanding of the problems. Nations should share knowledge and innovative technologies to achieve the goal of sustainability.
16. The full participation of women is essential to achieve sustainable development. The creativity, ideals and courage of youth and the knowledge of indigenous people are needed too. Nations should recognize and support the identity, culture and interests of indigenous people.
17. Warfare is inherently destructive of sustainable development. Nations shall respect international laws protecting the environment in times of armed conflict and shall cooperate in their further establishment.
18. Peace, development and environmental protection are interdependent and indivisible.

**Parameters of Sustainable Development:**

The goal of sustainable development is an outcome achieved through joint effort among several inter-related parameters and requiring coordination at both vertical and horizontal levels. There exists dynamic triangular relationship among three keys viz., Environmental, Economic and Social parameters.

The people centred at social parameter forms the broad base of triangle as active public participation holds an instrumental role. The interrelationship between population, environment and development is complex. Besides key factors, efficient manpower capacity building, institutional strengthening, including strong political will and effective implementation/monitoring mechanism play equally important role for successful outcome of sustainable development.

**Following parameters may be considered:**

1. **Environmental Sustainability:**

Environmental sustainability relates with maintenance of carrying capacity of natural resource base and life support systems. This emphasizes on area of conservation of biodiversity hot spots, increase in forest cover, watershed protection and adoption of holistic approach.

Equally important are reduction of environmental threats, environmental pollution and using environment friendly clean and green technologies to mitigate local to global level environmental problems such as biodiversity loss, climate change from an inter-generational equity perspective.

2. **Economic Sustainability:**

Economic sustainability provides important energy source like a battery to secure environmental and social sustainability. This emphasizes on promotion of economic self-sustenance of development projects through measures like adequate budgeting, budget transparency and financial incentive.

The focus area includes; alleviation of poverty, increase in per capita income, promotion of income generating activities including off farm employment and green micro-enterprises, establishment of mechanism of fair sharing of benefit and natural resource accounting.

3. **Social Sustainability:**

Social sustainability focuses on upgrading human environmental quality of life with fulfillment of basic needs and transforming man from most dangerous animal to most important creative resource. It emphasizes local communities to be well informed on sustainable ways of resource utilization.

It ensures active public participation at various level of development activity, collaborative efforts in conservation and development activities, improvement in public health, education and basic need, reduction of conflict among stakeholders on resource use. This will be derived through upgrading public environmental awareness, enhanced gender equity and self-confidence among local community with an emphasis on economically disadvantaged/marginalized groups.

4. **Institutional Sustainability:**

Plans and programmes without action represent futile exercise. Strict implementation and monitoring of relevant environmental policies, plans, laws, regulations and standards is indispensable to attain the goal of sustainable development. There should be adequate skilled and motivated manpower and strong institutional capacity to address environmental and social sustainability.

Focus area lies to achieve environmental quality of life such as reduced air, water, soil, noise pollution to accepted level of international standard and public confidence to get involved in environmental conservation activities. Institutional strengthening of project management should be efficient to deal with environmental problems having local, national, and regional to global level significance and including legally binding world conventions and treaties.

**Challenges of Sustainable Development:**

Sustainable development that fulfills people's needs of the present and future generations require radical improvements in eco-efficiency and fundamental renewal in technological systems. Since fundamental renewal system takes several decades to move from concept to market, it is imperative that we initiate renewing innovations in the shortest possible time to allow sufficient time to meet this challenge.

## 13. Let's sum up

- Ecology: branch of science that deals with interaction between living organisms with each other and their surroundings. Ecological systems are studied at several different levels from individuals and populations to ecosystems and biosphere level.
- Within the discipline of ecology, researchers work at four specific levels,

sometimes discretely and sometimes with overlap: organism, population, community, and ecosystem.

- There are many practical applications of ecology in conservation biology, wetland management, natural resource, city planning, community health, economics, basic and appliedscience, and human social interaction.
- Descriptive describes organisms and their interactions within ecosystems. This is the foundation of all ecological science. Functional studies proximate causes, the dynamic responses of populations and communities to immediate factors of environment. Evolutionary considers organisms and the relationships between organisms as historical products of evolution.
- A hypothesis can be defined as a tentative explanation of the research problem, a possible outcome of the research, or an educated guess about the research outcome.
- Probabilistic Ecological Models deal with the statistical probability of occurrence of certain phenomenon. Probabilistic Models are based on the exact knowledge of the most desirable information.
- Statistical approaches provide the means of understanding a process with some specified level of uncertainty. In statistics, an unknown true characteristic of a system is called a parameter.
- Remote sensing as a tool opened up new vistas of perception of things that exist too far or on extensive spatial scales. Nowadays there is a big assortment of satellite systems actively recording information about the Earth.
- Climate diagrams are brief summaries of average climatic variables and their time course. They have proven useful for a wide range of sciences, industry, teaching & are useful for planning and design.
- Abiotic factors are the non-living parts of an environment. These include things

such as sunlight, temperature, wind, water, soil and naturally occurring events such as storms, fires and volcanic eruptions. Biotic factors are the living parts of an environment, such as plants, animals and micro-organisms.

- Habitat is a set of the place of environmental conditions in which particular organism lives and adapt the situation accordingly. A niche is nothing but an idea or role played by organisms that how they can live in an environment including their diet, shelter, etc. Mainly niche is concerned with the factor of gaining energy by organisms and supplying it to other, inthe ecosystem.
- Population ecology is a sub-field of ecology that deals with the dynamics of species populations and how these populations interact with the environment. It is the study of how the population sizes of species change over time and space. Some of the most important characteristics of population are population density, natality, mortality, population growth andage distribution of population.
- A plant community is a collection or association of plant species within a designated geographical unit, which forms a relatively uniform patch, distinguishable from neighboring patches of different vegetation types. The components of each plant community are influenced by soil type, topography, climate and human disturbance.
- Each biotic community consists of very diverse organisms belonging to different kingdoms ofliving things. The number of species and abundance of population in communities also vary greatly. The organisms in a community depend upon each other as well as upon the non- living environment for food, shelter and reproduction.
- A diversity index (also called phylogenetic indices or phylogenetic metrics) is a quantitative measure that reflects how many different types (such as species) there are in a dataset (a community) and that can simultaneously take into account the phylogenetic relations among the individuals distributed among those types, such as richness, divergence or evenness.

- Ecological succession is the process of change in the species structure of an ecological community over time. The time scale can be decades, or even millions of years after a mass extinction. The community begins with relatively few pioneering plants and animals and develops through increasing complexity until it becomes stable or self-perpetuating as a climax community.
- Ecosystem may be defined as the system resulting from the integration of all living and non- living factors of the environment. An ecosystem has two major components; biotic and abiotic
- The bulk of any ecosystem is plants compared to which only a small fraction is animal life. Therefore, measurement of energy of an ecosystem primarily involves plants. And because plants represent the first or primary trophic level, plant production is measured as Gross Primary Production, which is equivalent to the energy fixed during photosynthesis.
- A food chain may be defined as the transfer of energy and nutrients from the source in plants through a series of organisms with repeated processes of eating and being eaten. Food chains are not always simple and isolated but are interconnected with one another. The interlocking pattern of food chains or a matrix of food chains, with all sorts of short circuits and connections is often called the food web or food net.
- Ecological pyramids are the graphic representations of trophic levels in an ecosystem. They are pyramidal in shape and they are of three types.
- A biome is an area classified according to the species that live in that location. Temperature range, soil type, and the amount of light and water are unique to a particular place and form the niches for specific species allowing scientists to define the biome. However, scientists disagree on how many biomes exist.
- Scientists divide ecosystems into terrestrial and non-terrestrial. Ecosystems may be further classified by their geographical region and dominant plant type six primary terrestrial ecosystems exist: Tundra, Taiga, Temperate deciduous forest,

Tropical rain forest, Grassland; and Desert.

- Biogeography is the study of the distribution of species and ecosystems in geographic spaceand through geological time. Organisms and biological communities often vary in a regular fashion along geographic gradients of latitude, elevation, isolation and habitat area.
- Environmental economics is an evolving discipline that developed as a result of environmental damage caused by economic activities and the pursuit of sustainable development. It is concerned with the design of environmental policies and their implementation.
- Sustainable development is the usage of natural resources for human needs in a way that preserves the environment that produces those resources so they can be used in the future.

## 14. Suggested Readings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7. Chapman, J. L. & Reiss, M. J. 1999. Ecology Principles and Applications. Cambridge

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8. Krishnamurthy, K.V. An Advanced Text Book on Biodiversity, 2003, Oxford & IBH Publishing Co. Ltd. Coyle.
9. http://www.biologydiscussion.com/
10. https://en.wikipedia.org/

## 15. Assignments

1. What is ecotone?
2. Who coined the term ecology?
3. Write about biotic factor of ecosystem.
4. Define character displacement.
5. Write the difference between Niche Width and Overlap?
6. Define deforestation.
7. What is net primary productivity?
8. Write a short note on remote sensing.
9. What is meant by climate diagram?
10. How fundamental niche and realized niche can be differentiated to each other?
11. Give examples of inverted pyramids.
12. Write short notes on any two:
    i. Ecological pyramid
    ii. Food web
13. Name a few biotic and abitoic components of an ecosystem.
14. Explain the analytic characters of community.
15. What is key stone species?
16. Give an account of general process of succession in nature.
17. What are the different types of speciation
18. Distinguish between allopatric and sympatric speciation.

19. What is guilds?
20. What is meant by carrying capacity?
21. Explain different characteristics of population ecology.
22. Differentiate between r and k-selection.
23. Give an account on survivorship curves.
24. What is physiognomy?
25. What is succession? Describe the causes, trends and basic types of succession.
26. Give an account of general process of succession in nature.
27. Differentiate between autogenic and allogenic succession.
28. Discuss about major biogeographical region of India.
29. Write a short note on biome.
30. What is meant by valuation?
31. Define environmental economics.
32. What is sustainable development?
33. Write the principles of sustainable development.

**All the materials are self writing and collected from ebook, journals and websites.**

# COURSE – BOTCOR T311

## (Biodiversity & Conservation)

**Core Theory Paper** **Credit: (Groups A+B) = 3**

## Group B (Biodiversity & Conservation)

## Content Structure

## 1. Introduction

Ecology is the branch of biology which studies the interactions among organisms and their environment. Objects of study include interactions of organisms with each other and with abiotic components of their environment. Topics of interest include the biodiversity, distribution, biomass, and populations of organisms, as well as cooperation and competition within and between species The two groups have to coexist in order to share the resources that are available within the environmental ecosystem. To understand about this mutual co relationship we need to study and understand ecology. Organism ecology: This studies how different living organisms respond to stimuli caused by physical environment.

Conservation biologists are concerned with the protection and sustainability of natural resources like air, water, land and wildlife. In post degree level in a scientific field like biology this course is needed for teaching and research.

## 2. Course Objectives

After completion of the course the learners will be able to:

1. To know about the nature of plant ecology
2. Distinguish between abiotic and biotic environment.
3. Describe different biogeographical region of India
4. To understand population and community ecology

Explain types of conservation and IUCN categories

## 3. Biodiversity: Concept, kinds/ levels, importance, methods of study, protection from depletion; Mega - diversity and Hotspots.

**What is biodiversity?**

The term biological diversity or biodiversity refers to the variety of life forms and habitatsfound in a defined area.

**UNEP (1992)** defines it"as the variety and variability of all animals, plants and micro-organisms and the ecological complexes of which they are a part".

Biodiversity is defined as "the intrinsically-inbuilt plus the externally-imposed variability in and among living organisms existing in terrestrial, marine and other ecosystem at a specific period of time".

The term biodiversity was coined by **W.G. Rosen (1985)**.

Diversity characterizes most living organisms, the our earth supports something like 5 to 10 million species of plants and animals (IUCN, 1980) which have been the result of 3 billion years of evolution involving mutation, recombination and natural selection.

Article 2 of the **CBD defines** "Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes biological diversity within species and ecosystems".

- "Biodiversity includes assemblages of plant, animals and micro-organisms, their genetic variability expressed and populations, their habitats, ecosystems and natural areas, the mosaic of which constitutes the landscape which gives the richness to the natural environment" (Denny, 1997).
- For the assessment of global biodiversity, it is defined as the total diversity and variability of living organisms and of the systems of which they are a part. This covers the total range of variation and variability among systems and organisms at the bioregional, landscapes, ecosystem, habitat (levels), and organismal level

down to species, populations, individuals and genes (genetic diversity) [Heywood, 1995].

According to Edward Wilson "Biodiversity is the combined diversity at all the levels ofbiological organization."

Biodiversity is an umbrella term covering diversity at genetic, species and ecosystem level. The convention on Biological Diversity defines biodiversity as "The variability among livingorganisms form all sources including, interalia terrestrial, marine and other aquaticecosystems and the ecological complexes of which they are a part; this includes diversitywithin species, between species and of ecosystems."

**History of Biodiversity**

The term 'diversity' is not new, rather has a long history, but 'biological diversity' came into use in scientific literature only in the 1980s. The term was first coined by Lovejoy who, however, did not provide any formal definition to it, but considered it as only the number of species (Lovejoy, 1980). Rosen in 1985 used the term 'biodiversity' in the first planning conference of the 'National Forum on Biodiversity', Washington D. C., on Sept. 1986.Wilson (1988) edited the proceedings of the conference titled Biodiversity, and this popularized the concept.

Convention on Biological Diversity in June 1992, constituted a historical commitment by all (many) nations of the world. For the first time, biodiversity was comprehensively addresses in this global treaty. At the same time the genetic diversity was considered and conservation of biodiversity was accepted as the common concern for the cause of human welfare (Gatson, 1998).

**How Many Species are there on Earth and How Many in India?**

Since there are published records of all the species discovered and named, we know howmany species in all have been recorded so far, but it is not easy to answer the question of how many species there are on earth. According to the IUCN (2004), the total number of plant and animal species described so far is slightly more than 1.5 million, but we have no clear idea of how many species are yet to be discovered and described. Some extreme estimates range from 20 to 50 million, but a more conservative and scientifically sound estimate made by Robert May places the global species diversity at about 7 million.

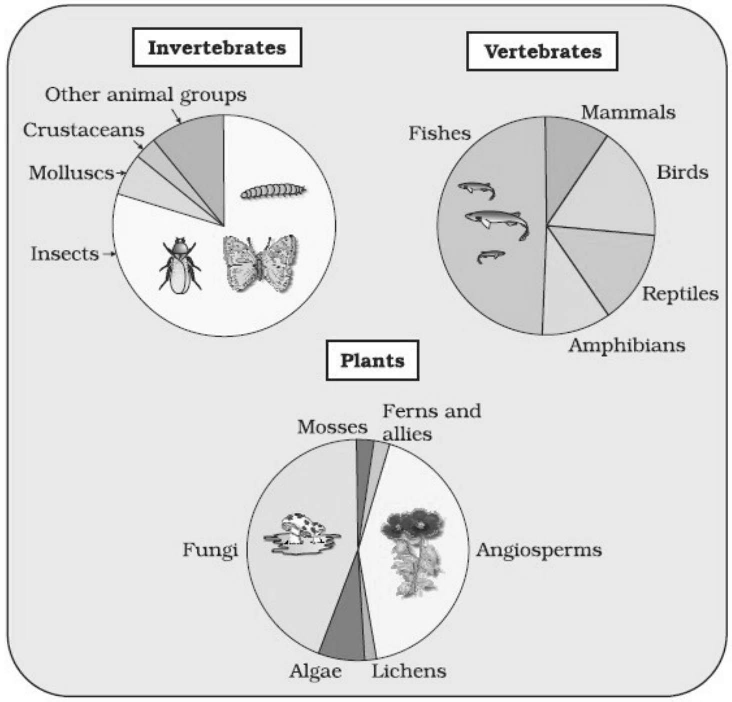



**Figure 15.1** Representing global biodiversity: proportionate number of species of major taxa of plants, invertebrates and vertebrates

Although India has only 2.4 per cent of the world's land area, its share of the global species diversity is an impressive 8.1 per cent. That is what makes our country one of the 12 mega diversitycountries of the world. Nearly 45,000 species of plants and twice as many of animals have been recorded from India. How many living species are actually there waiting to be discovered and named? If we accept Robert May's global estimates, only 22 per cent of thetotal species have been recorded so far.

Applying this proportion to India's diversity figures, we estimate that there are probably more than 1,00,000 plant species and more than 3,00, 000 animal species yet to be discovered and described.

**Table 15.1. Distribution of species in some major groups of flora and fauna in India.**

| Group-wise species Distribution | | | |
|---|---|---|---|
| **Plants** | **Number** | **Animals** | **Number** |
| 1. Bacteria | 850 | 8. Lower groups | 9979 |
| 2. Fungi | 23,000 | 9. Mollusca | 5042 |
| 3. Algae | 2500 | 10. Arthropoda | 57,525 |
| 4. Bryophytes | 2564 | 11. Pisces (Fishes) | 2546 |
| | | 12. Amphibia | 428 |
| 5. Pteridophytes | 1022 | 13. Reptiles | 1228 |
| 6. Gymnosperms | 64 | 14. Birds | 204 |
| 7. Angiosperms | 15,000 | 15. Mammals | 372 |

**Levels of biodiversity**

Biodiversity is commonly considered at three different levels:

1. Within species (intraspecific) diversity; usually measured in terms of genetic differencesbetween individuals or populations.
2. Species (interspecific) diversity, measured as a combination of number and evenness ofabundance of species.
3. Community or ecosystem diversity, measured as the number of different speciesassemblages.

Biodiversity, therefore, is usually considered at three hierarchical levels i.e. **Genetic, Speciesand Community and Ecosystem levels**.

**1. Genetic diversity:**

Genetic diversity refers to any variation in the nucleotides, genes, chromosomes, or whole genomes of organisms. This is the “fundamental currency of diversity” (Williams and Humphries, 1996) and the basis for all other organismal diversity.

- Genetic diversity is the sum total of genetic information, contained in the genes of individuals of plants, animals and microorganisms that inhabit the earth.
- It is needed by any species in order to maintain reproductive vitality, resistance to disease and the ability to adapt to changing conditions.
- It enables a population to adapt to its environment and to respond to natural selection.
- The amount of genetic variation is the basis of speciation.
- Genetic diversity within a species often increases with environmental variability.
- Such genetic variability has made it possible to produce new breed of crops plants and domestic animals, and in the world allowed species to adapt to changing conditions.

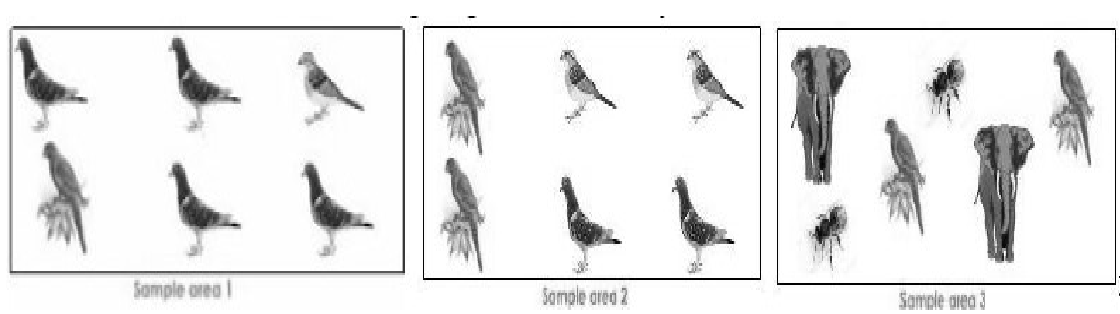
**2. Species diversity:**

Species diversity refers to variety of species in a region. Number of species per unit area is called species richness. Eveness or equitability differs due to difference in number of individuals in an area.

With increase in area, number of species increase. Usually, species diversity increases, if species richness is higher. Somehow, number of individuals among species may differ. This may lead to differences in evenness or equatibility. This also results to change in diversity. Some examples are as in the following figure:

Suppose in an area -1, there are three species of bird. Out of them two species bear only one bird each. Third species has four birds.

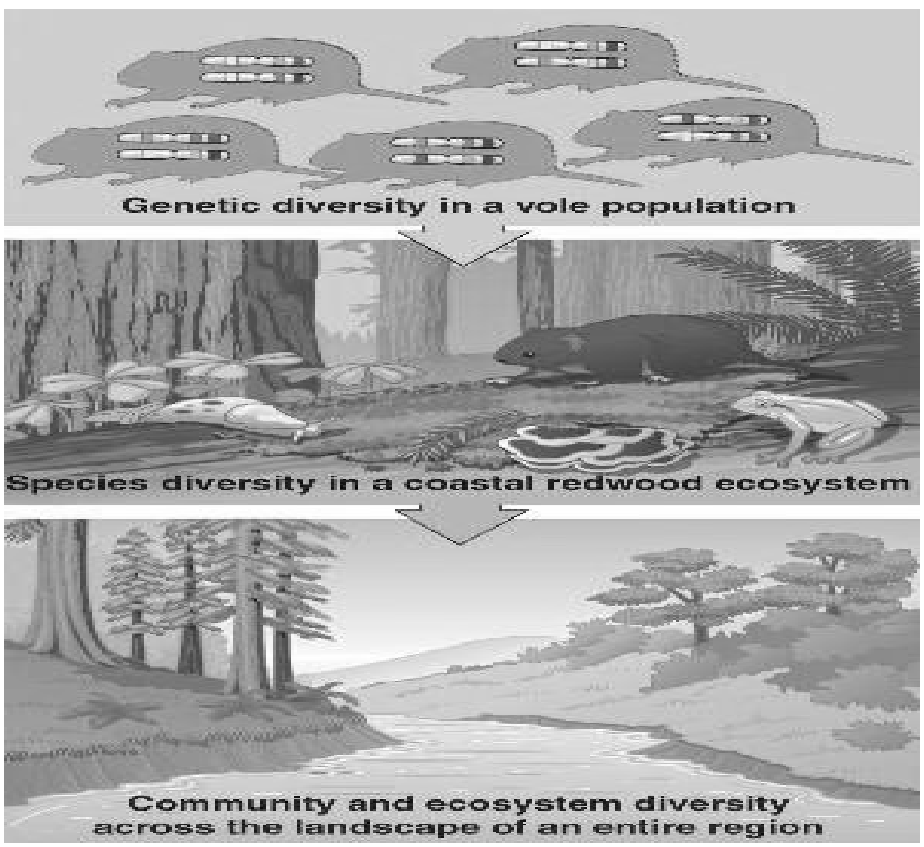
In area -2, there are 3 species each having 2 birds. This area represents greater



evenness. It is more diverse than area. In area-3, an insect, a mammal and a bird is also present.

**Ecological (Ecosystem) Diversity:**

The diversity of ecological complexes or biotic communities found in a given area. Indian ecosystem diversity is described at each of the three levels (biogeographical region, biotic province and biome). Largest of identified ecosystems has been the biogeographical zone. The vast area covered by biogeographical zone contains a wide diversity of smaller units called biotic provinces.Finally, within each biotic province, various kinds of biomes are distinguished. Biome classification broadly follows commonly used terminology, distinguishing between forests, grasslands, wetlands, deserts, and other such ecosystems on the basis of their physical appearance and dominant biotic or abiotic element. The enormous range of terrestrial and aquatic environments on earth has been classified into number of ecosystems.Few examples are:(i) Tropical rain forests,(ii) Grasslands, and (iii) Wetlands.Ecosystems differ not



only in the species composition of their communities but also in their physical structures (including the structures created by organisms). Some of the world's richest habitats are tropical moist forests. Although they cover only 7% of the world's surface, these areas contain atleast 50%, and possibly upto 90% of all plant and animal species.

**Measuring Biodiversity:**

There are various mathematical ways of measuring biodiversity, which calculate the number of species diversity in different regions. The measure of diversity of species is also known as species richness.

These are as follows:

**a. Alpha Diversity (with in community diversity)**:

It represents number of species in a given habitat. It represents the diversity of organisms sharing the same community/habitat. A combination of equitability/evenness and species richness is used to know that diversity prevalent within community or habitat.

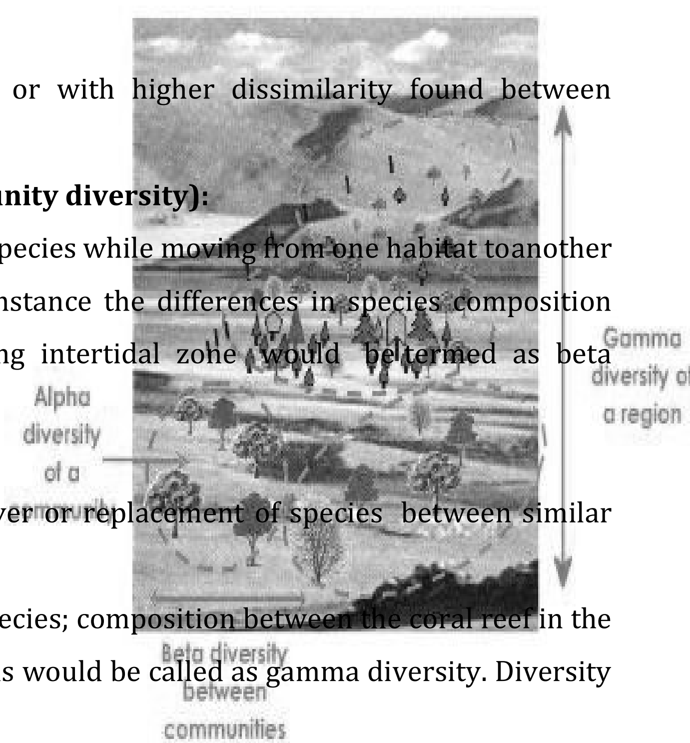
Differences can be observed in species composition of communities along different environmental ranges like moisture gradient, altitudinal gradients, etc. Beta diversity will be always high with increase in heterogeneity in habitats in a region or with higher dissimilarity found between communities.

**b. Beta Diversity (between community diversity):**

The rate of turnover or replacement of species while moving from one habitat toanother within a given geographical area. For instance the differences in species composition between a coral reef and the adjoining intertidal zone would be termed as beta diversity.

**c. Gamma Diversity:**

This term is used for the rate of turnover or replacement of species between similar habitats in different geographical areas. For example, the differences in species; composition between the coral reef in the Gulf of Kutch and in the Andaman Islands would be called as gamma diversity. Diversity



of habitats is the total landscape or geographical area is called gamma diversity.

**Importance**:

The biodiversity found on Earth today is the result of approximately 3.5 billion years of evolution. Until the emergence of humans, the earth supported more biodiversity than any other period in geological history. However, since the dominance of humans, biodiversity has begun a rapid decline, with one species after another suffering extinction.

The maintenance of biodiversity is important for the following reasons:

**1. Ecological stability**

Each species performs a particular function within an ecosystem. They can capture and store energy, produce organic material, decompose organic material, help to cycle water and nutrients throughout the ecosystem, control erosion or pests, fix atmosphericgases, or help regulate climate.

Ecosystems provide support of production and services without which humans could not survive. These include soil fertility, pollinators of plants, predators, decomposition of wastes, purification of the air and water, stabilisation and moderation of the climate, decrease of flooding, drought and other environmental disasters.

Research show that the more diverse an ecosystem the better it can withstand environmental stress and the more productive it is. The loss of a species thus decreases the ability of the system to maintain itself or to recover in case of damage. There are very complex mechanisms underlying these ecological effects.

**2. Economic benefits to humans**

- For all humans, biodiversity is first a resource for daily life. Such 'crop diversity' isalso called agrobiodiversity.
- Most people see biodiversity as a reservoir of resources to be drawn upon for the manufacture of food, pharmaceutical, and cosmetic products. Thus resource shortages may be related to the erosion of the biodiversity.

Some of the important economic commodities that biodiversity supplies to humankind are:

**i. FOOD :** crops, livestock, forestry, and fish

**ii. MEDICATION:** Wild plant species have been used for medicinal purposes since before the beginning of recorded history. For example, quinine (Used to treat malaria) comes from the bark of the Amazonian tree Cinchona tree; digitalis from the Foxglove plant (chronic hearttrouble), and morphine from the Poppy plant (pain relief).

According the National Cancer Institute of the USA, over 70 % of the promising anti-cancer drugs come from plants in the tropical rainforests. Animal may also play a role, in particular in research. It is estimated that of the 250,000 known plant species, only 5,000 have been researched for possible medical applications.

**iii. INDUSTRY:** fibres for clothing, wood for shelter and warmth. Biodiversity may be a source of energy (such as biomass). Other industrial products are oils, lubricants, perfumes, fragrances, dyes, paper, waxes, rubber, latexes, resins, poisons and cork can all be derived from various plant species. Supplies from animal origin are wool, silk, fur, leather, lubricants, waxes. Animals may also be used as a mode of transportation.

**iv. TOURISM & RECREATION:** biodiversity is a source of economical wealth for many areas, such as many parks and forests, where wild nature and animals are a source of beauty and joy for many people. Ecotourism in particular, is a growing outdoor recreational activity.

**3. Ethical reasons**

The role of biodiversity is to be a mirror of our relationships with the other living species, an ethical view with rights, duties, and education. If humans consider species have a right to exist, they cannot cause voluntarily their extinction. Besides, biodiversity is also part of many cultures' spiritual heritage.

**Methods of study**

Biodiversity assessments are considered important because measures of biodiversity are frequently interpreted as indicators of the wellbeing of ecological systems. Moreover, the patterns of spatial and temporal variations in diversity of different forms have and still continue to stimulate the minds of ecologists to discover, speculate, hypothesize and analyse information regarding different systems of interest. This has led to devising a huge range of indices and models for measuring diversity, which should be used with some caution in that they should be used only after their suitability has been evaluated under different habitats and situations.

Biodiversity assessments can generally follow certain approaches that describe biodiversity inthe way it has been defined by the Convention on Biological Diversity, to incorporate the diversity of ecosystems, diversity between species and within species. To name a few such approaches in biodiversity studies - habitat analysis, taxonomic approach, approaches that reflect on the dynamics of populations, associations and communities of the algae using different indices that can measure their diversity, dominance and similarities, metapopulation approaches that can define the populations' viability, dispersal and establishment dynamics, along with the scope of finding suitable but unoccupied habitats, and finally molecular and genomic approaches. Such assessments emphasize upon the species as the functioning entities and the categories by which all such diversity related information can be organized and retrieved. The methods to obtain reliable measures of species richness recognize sampling andidentification of species as the essential baseline for understanding their diversity and it goes without saying that properly conducted inventories will remain as the core of future endeavours. Few such approaches and indices of measurements that yield important and interesting results have been discussed here.

**Habitat analysis**

A study of the places in which different forms of organisms grow yield interesting sets of results. The habitat is described by geographic, physical, chemical and biotic characteristics. The overall habitat of many plant forms within a specific geographical or climatic unit is its macrohabitat. This can be further classified into smaller units called microhabitats. Habitat at both macro and microlevels need to be treated as multidimensional biophysical entities including the dimensions of temporal, spatial, physical-chemical and biotic as important measures. Such studies find many applications in the assessment of environmental impacts, vulnerability assessment, management of the desired species, preparation of inventories that can serve as baseline data for future studies, reflections on invasive species and habitat reclamation.

Diversity of habitat is in fact a partial measure of the diversity of species in a community. In general, it has been found that in both terrestrial and aquatic habitats diversity of species can be strongly correlated with the structural diversity of the habitat. Analysis of any habitat can yield adequate information only when it is executed over a considerable temporal and spatial scale. The initial analysis should deal with an account of the general macrohabitat description about the geographic, climatic, geologic and biotic factors most important to the inhabiting plant assemblage(s). A detailed analysis of some specific habitat components can follow, suchas information regarding weather along with water and soil quality. Finally a microhabitat study of specific plant assemblage(s) can be designed to evaluate the environmental factors that influence the presence or absence of one or more plant species that contribute towards the biodiversity of the plants specific to the location. The indices for such assessments can be chosen amongst the different habitat diversity indices and habitat rating indices depending on suitability of the specific index and with the objective of own study in mind.

**Populations, Associations and Communities**

A large number of basic measurements exist that are found suitable in describing populations and communities. The best known include measures of density, frequency, coverage and biomass. The other important measures that can be derived from such basic information include the likes of population distribution, species diversity and productivity. The census method among such general studies gives an account of the total count of all individuals in a population.

Sample collections for such studies involve quadrat analysis. Sampling should be done with the objective of the study in mind or on a more general note whether the intention is toexecute a qualitative or quantitative analysis.

Given the availability of large number of indices available for analysing such studies, it is often difficult to decide which among these poses as the best method of measuring diversity. One must initially assess the diversity measures to test their applicability and performance with one's own data. The selection procedure of the index to be used can further be strengthened by examining whether it fulfills the criteria of being able to discriminate between different habitats, whether it is proofed against its dependence on the available sample size, what component of diversity the researcher wishes to measure, and whether the index is widely in use and understood.

**Biodiversity Assessment Techniques**

Biodiversity is a broad term, and since the adoption of the Convention of Biological Diversity it is commonly defined in terms of three different components: intra-specific genes (genetic diversity), inter-specific species (species diversity) and ecosystems (ecological diversity), each of which have structural, compositional, and functional attributes. Given this complexity and the lack of knowledge on all three components, identifying, measuring and monitoring all three levels exhaustively proof to be impossible. An array of international and national initiatives has, therefore, sought to overcome this problem by trying to come up with simplified, yet significant methodologies of biodiversity assessments. One way is the identification of indicators – a subset of attributes that could serve as surrogates for total biodiversity. These were developed for various levels – national, regional and stand level. Indicators of biodiversity can be divided into two broad groups:

**i)biological or taxon based indicators**-Bioindicators are species, groups of species or biological communities whose presence, abundance and biological conditions, in real ecosystems or through the use of laboratory toxicity tests, to make inferences about the quality of the environment.

**ii) structure-based indicators** – stand and landscape level (spatial) features such as stand structure complexity, plant species composition and connectivity and heterogeneity

The selection of indicators differs for biodiversity monitoring and biodiversity inventory. Various criteria have been developed for the selection of indicators taking into accountbiological as well as logistical aspects. Relatively well-known taxa such as higher vertebrates (eg. mammals, birds), certain invertebrate groups (eg. butterflies, ants, land snails) and higher plants (particularly trees) are commonly used as indicator groups. Threatened species, endemic species, and economically or socially important species are often chosen as priorities for data collection. As much as it is impossible to assess each single element of biodiversity, itis also impossible in practice to inventorize every site. The knowledge of species habitat requirements, coupled with baseline data on climate, altitude, soil type, or vegetation cover, isused to predict their occurrence in areas not inventoried. Geographic information systems (GIS) are commonly used in biodiversity inventory techniques.

Some selected biodiversity assessment techniques include:

### 1.1. Baseline studies

The techniques described under this section are used for collecting general data on biodiversity mainly within the frame of national biodiversity conservation planning. They include biodiversity inventories, the identification and prioritization of areas rich in biodiversity as well as gap analysis. The techniques vary from using an advanced and highly technical approach (e.g. REA) to simpler ground-based inventories (e.g. RBA).

#### Rapid Biodiversity Assessment (RBA)

A very rapid, cheap and attractive method to assess the **relative biodiversity value of different sites**, provided they are assessed using the same indicator groups of species. RBA isbased on the premise that certain aspects of biological diversity can be quantified without knowing the scientific names of the species involved. The main characteristic of RBA is the minimization of the formal taxonomic content in the classification and identification oforganisms.

Data are gathered on certain groups of organisms. Several groups, chosen as good "predictor sets" of biodiversity are needed at each location inventoried. Appropriate groups are ones that are relatively abundant, have high species richness, contain many specialist species, are easy to sample, and have taxonomic traits amenable to RBA methods. RBAs focus on invertebrate groups, such as butterflies, ants, termites, certain beetle families, grasshoppers and spiders.

**Rapid Assessment Program (RAP)**

The RAP conducts preliminary assessments of the biological value of poorly known areas. RAP teams usually consist of experts in taxonomically well-known groups such as higher vertebrates (e.g., birds and mammals) and vascular plants, so that the ready identification of organisms to the species level is possible. The biological value of an area can be characterised by species richness, degree of species endemism (i.e., percentage of species that are found nowhere else), the uniqueness of the ecosystem, and the magnitude of the threat of extinction. RAPs are undertaken by identifying potentially rich sites from satellite images/aerial reconnaissance, and then sending in ground teams to conduct field-survey transects. Suchfield trips last from two to eight weeks, depending on the remoteness of the terrain.

**Rapid Biological Inventories (RBI)**

"The goal of rapid biological inventories is to catalyze effective action for conservation in threatened regions of high biological diversity and uniqueness. During rapid biological inventories, which typically take a month, scientific teams focus primarily on groups of organisms that indicate habitat type and condition and that can be surveyed quickly and accurately. These inventories do not attempt to produce an exhaustive list of species or higher taxa. Rather, the rapid surveys identify the important biological communities in the site or region of interest and determine whether these communities are of outstanding quality and significance in a regional or global context. The rapid biological inventory teams use protocols that are specific to the organism groups under study and which are often modified tomeet the demands of a particular expedition.

**Rapid Ecological Assessment (REA)**

Rapid Ecological Assessment is a technique used to assess biodiversity in large, poorly-studied, or exceptionally biodiverse areas. The REA process consists of a series of increasingly refined analyses, with each level further defining sites of high conservation interest. The levels involved are satellite observation; airborne remote sensing; aerial reconnaissance; and field inventory. Analysis of satellite images is used to produce maps of eco-regions, land cover and priority areas; while integration with data from airborne sensors and aerial reconnaissance produces more detailed maps, extended to cover vegetation types and ecological communities. These are used to direct the cost-effective acquisition of biological and ecological data through stratified field sampling. Such data are used to identify

priority sites. Spatially-referenced information is managed by GIS, allowing easy data handling and generation of maps.

**Gap Analysis**

The technique "Gap Analysis" is essentially a coarse-filter approach to biodiversity conservation. It is used to identify gaps in the representation of biodiversity within protected areas. The goal is to ensure that all ecosystems and areas rich in species diversity are adequately represented in protected areas. Gaps in the protection of biodiversity are identified by superimposing three digital layers in a Geographical Information System (GIS), namely maps of vegetation types, species distributions and land management use. A combination of all three layers can be used to identify individual species, species-rich areas and vegetation types that are either not represented at all or are under-represented in existing reserves. In practice, vegetation, common terrestrial vertebrate species, and endangered species are usedas surrogates to represent overall biodiversity.

### 1.2. Monitoring and Modeling Techniques Biodiversity Monitoring Techniques

The initial phase in biodiversity surveys is estimating diversity at one point in time and location (in other words, knowing what species or communities are present). The second phase, monitoring biodiversity, is estimating diversity at the same location at more than one time period for drawing inference about change. Wilson, et al. (1996) identified attributes of biodiversity that can be assessed at each level of ecological organization. At the landscape level, attributes that could be monitored include the identity, distribution, and proportions of each type of habitat, and the distribution of species within those habitats. At the ecosystem level, richness, evenness, and diversity of species, guilds, and communities are important. At the species level, abundance, density, and biomass of each population may be of interest. And, at the genetic level, genetic diversity of individual organisms within a population is important. It is best to assess and interpret biodiversity across all these levels of organization by using various approaches at several spatial and temporal scales.

Identifying monitoring questions is a critical and difficult step. It could be accomplished through an interdisciplinary process with experts knowledgeable of the issues at the appropriate level (e.g., landscape, ecosystem, species, genetic, etc.) and should be considered an iterative process that is adapted as new information becomes available.

Monitoring questions can be derived from information available in watershed analysis, late- successional reserve (LSR) assessments, or regional assessments. The monitoring questions are ranked as low, moderate, and high priority. Ultimately, management must determinewhich monitoring questions should be addressed. Methods selected for monitoring biodiversity depend on management objectives. A management objective of maintaining species viability would involve different monitoring methods than an objective of restoring inherent disturbance regimes. Selecting the appropriate biodiversity monitoring approach includes identifying methods that will provide answers to specific monitoring questions. A wide range of methods are available, and selection of methods would be made based on costs, available resources, and statistical constraints. It might be helpful, if not absolutely necessary, to consult a statistician at this stage to determine sampling sizes, strategies, and statistical power. Periodically, data collected from monitoring should be analyzed and integrated into management strategies based on the knowledge gained. If monitoring reveals that adjustments need to be made in management strategies, then this becomes a decision. Several examples of monitoring biological diversity at each level of ecological organization have been described below:

**Landscape Monitoring:** A landscape has been defined as a land area with groups of plant communities or ecosystems forming an ecological unit with distinguishable structure, function, geomorphology, and disturbance regimes. Landscape diversity is the number of ecosystems, or combinations of ecosystems, and types of interactions and disturbances present within a given landscape. The relevance of landscape structure to biodiversity has been established through ecological studies. Landscape features such as patch size, heterogeneity, connectivity, etc., have major implications to species composition, distribution, and viability. Because of this, it may be important that managers monitor elements of biodiversity at the landscape scale to meet species viability requirements. There exist several approaches to assessing biological diversity at a landscape scale. Each of these approaches relies on the use of geographic information systems (GISs) and requires mapped vegetation and other layers that can be analyzed with GIS technologies. Landscape pattern measurements, or metrics, can be classified into three categories: patch, class, and landscape. The various metrics in use include Patch metrics, Class metrics and Landscape pattern metrics.

Patch metrics describe the attributes of individual patches of vegetation. The size, shape,edge, or nearest-neighbor relations of individual patches are measured.

Class metrics describe those same patch attributes as the mean, minimum, maximum, or variance for a class of mapped landscape attributes (e.g., late-successional forest).

Landscape pattern metrics describe these and other attributes for all landscape classes combined without distinction between different classes. For example, mean patch size might be measured for all patches in a landscape, instead of for just one vegetation type (class).

**Community Monitoring:** A community comprises the populations of some or all species coexisting at a site. An ecosystem includes the abiotic aspects of the environment and the biotic community. Monitoring at this level is important to the maintenance of ecosystem functions and integrity that have been identified as a main theme of ecosystem management. Land managers may be interested in monitoring communities or ecosystems to determine if current management strategies meet legal and social obligations to sustain the health, diversity, and productivity of ecosystems.

Monitoring methods include by measuring the number and relative abundance of species in a community or ecosystem, often referred to as species diversity. Species diversity is a function of the number of species present (richness) and the evenness or equitability (relative abundance) of each. Although species diversity and species richness are often positively correlated, situations do exist in which increases in species diversity are accompanied by decreases in species richness. Care should be taken therefore, when only species richness (counts of the number of species) is used to evaluate biodiversity. On the other hand, species diversity indices also should be carefully used because it may be hard to interpret differences in species composition at different sites. For example, two sites may have similar indices of diversity but have entirely different species composition. One site may be primarily exotic species, whereas the other mainly native or endemic species.

**Guild Monitoring:** Some investigators have taken a different viewpoint by lumping species into functional groups or guilds. Many approaches for grouping species based on habitat or behavioral similarities and their potential problems have been discussed in the literature. An approach to the same is in which species are grouped into guilds based on their function in the ecosystem, and then the relative importance of each guild is considered based on how a change in their abundance affects ecosystem and community processes.

**Population Monitoring:** A population is defined as all individuals of one species occupyinga defined area and usually isolated to some degree from other similar groups. A species is generally defined as a group of organisms formally recognized as distinct from other groups. Monitoring at this level may have the most relevance to meeting the species or population viability objectives. For example, land managers may decide to monitor a species or population in order to measure trends. This would be important to determine if management strategies maintain population viability. Monitoring methods at this level are sufficiently enriched as most monitoring of biodiversity has occurred at the population- species level. Deciding which species or population to monitor has received considerable discussion, and nosingle approach is without pitfalls.

Five categories of species may be selected for monitoring. These include (1) ecological indicators—species that signal the effects of perturbations on a number of other species with similar habitat requirements; (2) keystones—species on which the diversity of a large part of a community depends; (3) umbrella species—species with large area requirements, which if conserved, many other species also would be conserved; (4) flagship species — popular, charismatic species; and (5) vulnerable species —species that are rare, genetically impoverished, or for some reason prone to extinction. When determining which species are best to monitor as bioindicators, it is appropriate to consider species of invertebrates, fungi, lichens, and amphibians, as well as vertebrates and vascular plants.

Monitoring a species or population may include counting of individuals but most often involves the monitoring of habitat that is used by or is important to a species. It has been pointed out that monitoring habitat variables does not alleviate the need to monitor populations because the presence of habitat is no guarantee that the species is present. Conversely, monitoring only population variables could be misleading because someindividuals may occur in areas of marginal habitat. The most reliable approach would include monitoring both habitat and population variables.

**Population Viability Analysis:** (PVA) estimates what conditions are necessary for a population to persist for a given period of time in a given place. The PVA allows for a prediction of the possible trend of a population and can provide insights into why a population may be decreasing. One of the disadvantages of a quantitative PVA is the rigorous data setthat is needed to complete the analysis. These data are often expensive to obtain and require several years or decades of study. Because of the need to have such a rigorous and extensive data set, PVA may be too cumbersome to use to monitor biodiversity. When such data are available, however, PVA may be useful in establishing baseline population information to predict how management actions might affect viability. Recently, a new approach has been used to develop a qualitative PVA relying on the professional judgement of scientists familiar with a species or group of species. This qualitative approach has the advantage of not requiring such a rigorous data set, yet still meets the essential criterion of a PVA, to providean estimate of the likelihood that a population will persist over a given time period.

**Genetic Monitoring:** Genetic diversity refers to the breadth of genetic variation within and among individual populations and species. Genetic variation is essential for the long-term survival of endangered species, especially those that occur in fast-changing or harsh environments. Genetic diversity is a necessary prerequisite for future adaptive change or evolution, and presumably, populations and species that lack genetic variation are at greater risk of extinction. Land managers may decide to monitor genetic diversity to determine if management strategies are meeting the requirements for species viability. Monitoring methods include determining which population or species should be monitored for genetic diversity would be identified when specific monitoring questions are developed. Most of the time, however, the resources available in which to conduct genetic diversity studies will bethe limiting factor in their application. The following criteria has been recommended in the selection of populations or species for this level of monitoring:

(1) Species or populations that are limited in their numbers and distribution (e.g., endangered, threatened, and candidate species);
(2) Populations that are naturally fragmented or have become fragmented as a result of human activities and the likelihood of genetic interchange among component populations is low;
(3) Populations that are on the edge of a species range, and
(4) Species that naturally occur at low densities but may have wide distribution (e.g., large carnivores).

**Morphological Monitoring:** The measurement of morphological variation is the most easily obtained indicator of genetic diversity. Morphological measurements often can be obtained in the field or from field specimens, not requiring laboratory studies. Another advantage is that morphological characters may be ecologically adaptive, meaning they are good indicators of genetic variation, local differentiation, or ecotypes. This method is often the most realistic when the biochemical analysis are impractical. Perhaps the greatest disadvantage is the assumption that morphological variation is a reliable indicator of underlying genetic variation. This assumption can be difficult to validate unless it is done in conjunction with allozyme or DNA analysis.

**New Approaches to Biodiversity**

**Assessment People's Biodiversity Register (PBR) exercise**

The evolution of human societies over several millennia is closely related to plants and animals. The domestication of crop plants and farm animals about 12000 years ago revolutionized the human civilization by creating more stabilized societies. The early historic and medieval period gradually reduced human interaction with the wild plants and animals. The development of modern science and technologies during the industrial and post- industrial period did not do away with our link to nature. Different groups of people continue to depend on natural resources at varying scales. Some draw resources from across continents while others within a country or a region. There are also people continue to depend on locally available biodiversity and bio-resources for their livelihoods. Such population who are directly dependent on local biological resources have, through their keen sense of observation, practices, and experimentation developed and established a body of knowledge that is passed on from generation to generation. Some are widespread traditional knowledge like cultivation practices; others are highly specialized such as bone setting or jaundice, which are generally passed only to close members of the family.

India is land of biological and cultural diversity. It is one of the ten-mega bio-diverse countries of the world. It also the home of a large number of tribal groups, pursing different kinds of nature based livelihoods. In addition, a large number of farming and fishing communities and nomadic groups possess traditional knowledge of varying degrees. The development of modern science and technologies notably biotechnology and information technologies have increased the value of biodiversity and associated knowledge including traditional knowledge (TK) .The growing importance of biodiversity, bio-resources and associated knowledge is fairly well understood. The first step towards conservation or sustainable utilization of biodiversity is its documentation. Biodiversity and associated knowledge is found in different ecosystems, under different legal management regimes and hence the results and manner of documentation will also differ.

The preparation of People's Biodiversity Registers are an initiative to document people's knowledge regarding biodiversity resources of their areas pertaining to status, use, history, changing trends, forces driving such changes, the gainers and losers in these processes and also the local people's perceptions of how these resources should be managed. These documents are capable of bringing together important locality specific information on bioresources and the ecological processes affecting them. These exercises are capable of leading to recognition and promotion of conservation oriented local practices and help mobilize and motivate communities to prudently manage local biodiversity resources. Assuch, these registers have an important role to play in promoting conservation, sustainable use and equitable sharing of benefits of biodiversity resources in future. Thus the process of preparation of PBRs and the resultant documents are of immense importance in promoting more sustainable, flexible, participatory systems of management and in ensuring a proper access and benefit sharing from economic use of the living resources to the local communities.

The Biological Diversity Act, 2002 (No. 18 of 2003) was notified by Government of India on 5th February, 2003. The Act extends to the whole of India and reaffirms the sovereign rights of the state over its biological resources. Subsequently the government of India published Biological diversity Rules, 2004 (15th April, 2004). The Rules under section 22 states that 'every local body shall constitute a Biodiversity Management Committee (BMC's) within its area of jurisdiction'.

**People's Biodiversity Registers and the role of the Biodiversity Management Committee:** The mandate of the Biodiversity Management Committee has been clearly highlighted in the Biodiversity Rules 2002 as follows:

- The main function of the BMC is to prepare People's Biodiversity Register in consultation with the local people. The Register shall contain comprehensive information on availability and knowledge of local biological resources, their medicinal or any other use or any other

- The other functions of the BMC are to advice on any matter referred to it by the State Biodiversity Board or National Biodiversity Authority for granting approval, to maintain data about the local vaids and practitioners using the biological resources.The National Biodiversity Authority shall take steps to specify the form of the People's Biodiversity Registers, and the particulars it shall contain and the format for electronic database.

- The National Biodiversity Authority and the State Biodiversity Boards shall provide guidance and technical support to the Biodiversity Management Committees for preparing People's Biodiversity Registers.
- The People's Biodiversity Registers shall be maintained and validated by the Biodiversity Management Committees.

**People's Biodiversity Registers and Role of the Technical Support Group (TSG):** The Technical Support Group (TSG) consists of experts drawn from various disciplines and line departments, universities, research institutes, colleges and schools and non-governmentalorganizations. The Technical Support Group provides technical inputs and advice to theBMCs on identification of plants and animals, monitors and evaluates the PBR exercise, examines confidential information and advices on legal protection, maintains a database of local and external experts on biodiversity.

**People's Biodiversity Registers and the role of State Biodiversity Board (SBB):** The State Biodiversity Board (SBB) provides necessary training to the Technical Support Group (TSG) of the district and enable smooth functioning and aid in networking for creation and maintenance of People's Biodiversity Registers (PBRs).

**People's Biodiversity Registers and the role of National Biodiversity Authority (NBA):**The National Biodiversity Authority provides guidance and technical support to the Biodiversity Management Committee (BMC) for preparing People's Biodiversity Register The present manual guidelines have been drafted by the National Biodiversity Authority taking into consideration different ecosystems and include rural urban and protected areas. The guidelines may be customized and further information may be added to enrich the effort. It is important to keep in mind some of the issues related to PBRs:

- It is to be undertaken in a participatory mode involving varying sections of villagesociety.
- While documenting, the knowledge and views of both genders are to be

recorded.

- Information provided by people need to be collated, analysed and crosschecked by the members of the Technical Support Group (TSG) before documentation.
- The PBR is an important base document in the legal arena as evidence of priorknowledge and hence careful documentation is necessary.
- The document should be endorsed by the BMC and later publicized in the Gram Sabha
  / Gram Panchayat / Panchayat Samiti. The document can be a very useful tool in the management and sustainable use of diversity. The document can also be a very useful teaching tool for teaching environmental studies at schools, colleges and university level.
- The document should be periodically updated with additional and new information as and when generate.

**The PBR Process:** The preparation of People's Biodiversity Registers (PBRs) involves the active support and cooperation of a large number of people who need to share their common as well as specialized knowledge. One of the first steps for preparing a PBR is to organize a group meeting to explain the objectives and purpose of the exercise. Different social groups in the village need to be identified for purpose of data collection from those groups. In an urban situation, spots where biodiversity are important need to be identified for the purpose of the study and documentation. The documentation process includes information gathered from individuals through detailed questionnaire, focused group discussion with persons having knowledge and published secondary information.

**Documentation of Traditional Knowledge (TK) related to biodiversity:** Documentation ofknowledge of individuals with regard to biodiversity and its uses is an important part of PBR. Every effort should be made to identify the persons with proven knowledge of local biodiversity; special attention should be given to the elderly persons who can also provide information on the biodiversity which was available in the past but no longer seen at present. In some cases focus group discussion may be held for the purpose of documentation.

**PBR Methodology:** The PBR is a participatory process requiring intensive and extensive consultation with the people. The objectives and purpose is to be explained in a groupmeeting in the presence of all sections of people in the Panchayat, members of the BMC, students, knowledgeable individuals and all those interested in the effort. Documentation includes photographs (including digital images), drawings, audio and video recordings and other records like printed material.

**Process in PBR Preparation:**

**Step 1** Formation of Biodiversity Management Committee (BMC)

**Step 2** Sensitization of the public about the study, survey and possible management

**Step 3** Training of members in identification and collection of data on biological resourcesand traditional knowledge

**Step 4** Collection of data. Data collections includes review of literature on the natural resources of the districts, Participatory Rural Appraisal (PRAs) at village level, housel hold interviews, individual interviews with village leaders and knowledgeable individuals, household heads, key actors of the Panchayat Raj Institutions and NGOs and direct field observations.

**Step 5** Analysis and validation of data in consultation with technical support group and BMC

**Step 6** Preparation of People's Biodiversity Register (PBR).

**Step 7** Computerization of information and resources.

**Protection from depletion**

Biodiversity is being depleted by the loss of habitat, fragmentation of habitat, over exploitation of resources, human sponsored ecosystems, climatic changes, pollution invasive exotic spices, diseases, shifting cultivation, poaching of wild life etc.

Since the human beings are enjoying all the benefits from biodiversity, they should take proper care for the preservation of biodiversity in all its form and good health for the future generation i.e., the human being should prevent the degradation and destruction of the habitatsthereby maintaining the biodiversity at its optimum level.

Conservation of biodiversity is protection, upliftment and scientific management of biodiversity so as to maintain it at its threshold level and derive sustainable benefits for the present and future generation. In other words, conservation of bio-diversity is the proper management of the biosphere by human beings in such a way that it gives maximum benefits for the present generation and also develops its potential so as to meet the needs of the future generations.

**Mainly the conservation of biodiversity has three basic objectives:**

(a) To maintain essential ecological processes and life supporting systems.

(b) To preserve the diversity of species.

(c) To make sustainable utilisation of species and ecosystems.

**Strategies for Conservation of Biodiversity:**

The following strategies should be undertaken in order to conserve biodiversity:

(1) All the possible varieties (old or new) of food, forage and timber plants, live stock,agriculture animals and microbes should be conserved.

(2) All the economically important organisms in protected areas should be identified andconserved.

(3) Critical habitats for each species should be identified and safeguarded.

(4) Priority should be given to preserve unique ecosystems.

(5) There should be sustainable utilisation of resources.

(6) International trade in wild life should be highly regulated.

(7) The poaching and hunting of wildlife should be prevented as far as practicable.

(8) Care should be taken for the development of reserves and protected areas.

(9) Efforts should be made to reduce the level of pollutants in the environment.

(10) Public awareness should be created regarding biodiversity and its importance for theliving organisms.

(11) Priority should be given in wildlife conservation programme to endangered species over vulnerable species and to vulnerable species over rare species.

(12) The habitats of migratory birds should be protected by bilateral and multilateralagreement.

(13) The over exploitation of useful products of wild life should be prevented.

(14) The useful animals, plants and their wild relatives should be protected both in theirnatural habitat (in-situ) and in zoological botanical gardens (ex-situ)

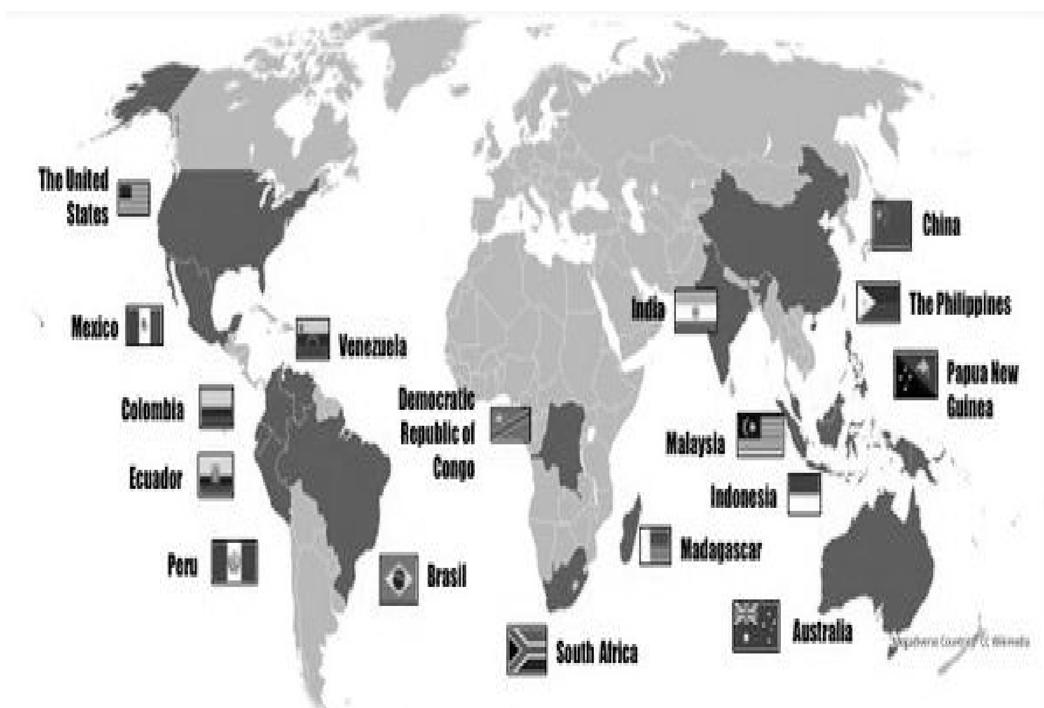
(15) Efforts should be made for setting up of National parks and wild life sanctuaries tosafeguard the genetic diversity and their continuing evolution.

(16) Environmental laws should be strictly followed.

**Megadiversity and Hotspots**

The term megadiverse country refers to any one of a group of nations that harbour the majority of Earth's species and high numbers of endemic species. Conservation International identified 17 megadiverse countries in 1998. Many of them are located in, or partially in, tropical or subtropical region.

The 17 megadiverse countries are : Australia, Brazil, China, Colombia, Democratic Republic of the Congo, Ecuador, India, Indonesia, Madagascar, Malaysia, Mexico,Venezuela, Papua, New Guinea, Peru, Philippines, South Africa, United States .



**India as a megadiverse country:**

India has tremendous biodiversity, genetic as well as of species and ecosystems. It contains over 7 per cent of the world's biodiversity on 2.5 per cent of the Earth's surface. This diversity can be attributed to the vast variety of landforms and climates resulting in habitats ranging from tropical to temperate, and from alpine to desert.

- India is one of the world's 'mega diversity' countries. It is ranked ninth in the world interms of higher plant species richness. At the ecosystem level, India is also well- endowed, with ten distinct biogeographic zones.
- It also contains two of the world's 25 biodiversity hotspots, because of their extraordinarily high levels of species-richness and endemicity, and threatened status.
- India is considered to be the centre of origin for the following crop species pigeon pea, egg plant cucumber, possibly cotton and sesame. But for millennia, numerous other crop species have been introduced to India and adapted to localised conditions.The country has become an important centre of diversity of a great many domesticated species, including various cereals, millets, legumes, vegetables, temperate and tropical fruits, fibre crops, medicinal and aromatic plants.
- The number of plant species in India is estimated to be over 45,523 representing about

  11.8 per cent of the world's flora. These include over 17,500 flowering plants ofwhich 4,950 species are endemic to the country.
- India's faunal wealth is equally diverse. The total number of animal species is estimated at 91,307, representing about 7.46 per cent of the world's fauna. India's known animal diversity includes about 8,61,696 insects, 21,723 fish, 240 amphibians,

  460 reptiles, 1,232 birds and 397 mammals. In also includes about 86,413 invertebrates. Among amphibians found in India, 62% are unique to this country. Among lizards, of the 153 species recorded, 50% are endemic. High endemism has also been recorded for various groups of insects, marine

worms, centipedes, mayflies and fresh water sponges.

- ❖ The ancient practice of domesticating animals has resulted in India's diverse livestock, poultry and other animal breeds. India has 26 breeds of cattle, 40 breeds of sheep, 20 breeds of goats, 8 breeds of camels, 6 breeds of horses, 2 breeds of donkeys and 18 breeds poultry birds. India also contains vast microbial diversityAlthough exact numbers of viruses, microscopic algae and other microscopic organisms are not known. India has at least 850 species of bacteria and virus, also 12,500 of fungi.
- ❖ It is estimated that 32% of Indian plants are endemic to the country and found nowhere else in the world. Among the plant species the flowering plants have a much higher degree of endemism, a third of these are not found elsewhere in the world.

**Biodiversity Hotspots:**

A biodiversity hotspot is a biogeographic region with a significant reservoir of biodiversity that is under threat from humans. A hotspot is an area which faces serious threat from human activities and supports a unique biodiversity (endemic, threatened, rare species) with representatives of evolutionary of speciation and extinction.
The concept of biodiversity was given by Norman Myers (1988).

**To qualify as a biodiversity hotspots on Myers 2000 edition of the hotspot map, a region must meet two strict criteria**:

1. It must contain at-least 0.5% or 1500 species of vascular plants of the world.
2. It has to have lost at least 70% of its primary vegetation.

Myers originally recognised 25 hotspots but recently the Conservation International has added 9 more biodiversity hotspots which make the present number to 34. These sites support nearly 60% of the world's plant, bird, mammal, reptile, and amphibian species, with a very highshare of endemic species.

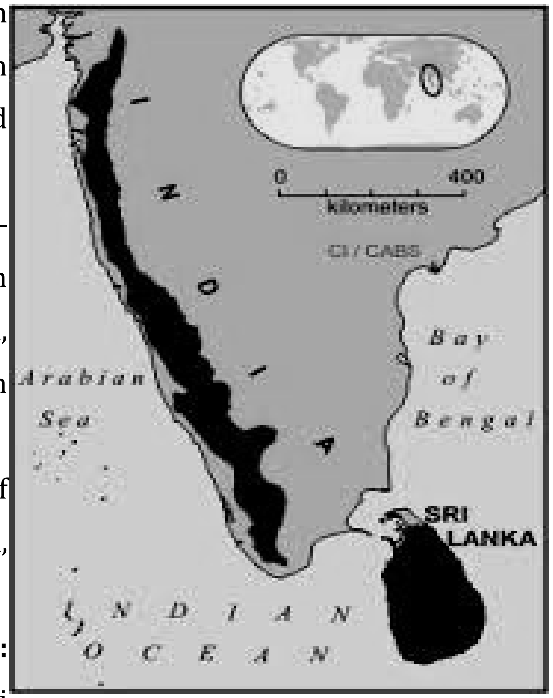
**BIODIVERSITY HOTSPOTS IN INDIA**

**1. Himalaya:** Includes the entire Indian Himalayan region (and that falling in Pakistan, Tibet, Nepal, Bhutan, China and Myanmar)

**2. Indo-Burma:** Includes entire North-eastern India, except Assam and Andaman group of Islands (and Myanmar, Thailand, Vietnam, Laos, Cambodia and southern China)

**3. Sundalands:** Includes Nicobar group of Islands (and Indonesia, Malaysia, Singapore, Brunei, Philippines)

**4. Western Ghats and Sri Lanka:** Includes entire Western Ghats (and Sri Lanka)




The hotspots are rich in floral wealth, reptiles, amphibians, mammals and also in their endem

**1. The Western Ghats:**

**About the region:**

The Western Ghats are a chain of hills that run along the western edge of peninsular India. They are also known as Sahyadri Mountains. They receive high rainfall. It run parallel to the west coast of India and
constitute more than 1600 km strip of forests in the states of Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala.

**Flora:**

These regions have moist deciduous forest and rain forest. The region shows high species diversity as well as high levels of endemism. There are over 6000 vascular plants belonging toover 2500 genera in this hotspot, of which over 3000 are endemic.
Much of the world's spices such as black pepper and cardamom have their origins in the

Western Ghats. Many economically important plants such as banana, rice, ginger etc. have spread to other parts of the country from here.

**Fauna:**

Nearly 77% of the amphibians and 62% of the reptile species found here are found nowhere else. The region also harbours over 450 bird species, about 140 mammalian species, 260 reptiles and 175 amphibians. Over 60% of the reptiles and amphibians are completely endemic to the hotspot. Remarkable as this diversity is, it is severely threatened.

**2. The Eastern Himalayas:**

**About the region:**

The Eastern Himalayas is the region encompassing Bhutan, northeastern India, and southern, central, and eastern Nepal. The region is geologically young and shows high altitudinal variation. Together, the Himalayan mountain system is the world's highest, and home to the world's highest peaks, which include Mount Everest and K2.

**Flora:**

There are an estimated 10,000 species of plants in the Himalayas, of which one-third are endemic and found nowhere else in the world. Five families —Tetracentraceae,

Hamamelidaceae, Circaesteraceae, Butomaceae and Stachyuraceae — are completely endemic to this region.

Many plant species are found even in the highest reaches of the Himalayan Mountains, For example, a plant species Ermania himalayensis was found at an altitude of 6300 metres in northwestern Himalayas.

**Fauna:**

Few threatened endemic bird species such as the Himalayan Quail, Cheer pheasant. Western tragopans are found here, along with some of Asia's largest and most endangered birds suchas the Himalayan vulture and White-bellied heron.

The Eastern Himalayan hotspot has nearly 163 globally threatened species including the One- horned Rhinoceros (Rhinoceros unicornis), the Wild Asian Water buffalo (Bubalus bubalis) and in all 45 mammals, 50 birds, 17 reptiles, 12 amphibians, 3 invertebrate and 36 plant species. The Relict Dragonfly (Epiophlebia laidlawi) is an endangered species found here with the only other species in the genus being found in Japan.

## 4. Threats to Biodiversity: Causes of threats; Concepts of rare, vulnerable, endangered and threatened plants (IUCN categories).

Biodiversity is considered as a reservoir of resources to be used for the manufacture of food, medicine, industrial products, etc. But with an increased demand of rapid population growth, biodiversity is gradually depleting. A number of plants" and animal species have already become extinct and many are endangered.

**Causes of threats:**

**Habitat Loss:**

The natural habitat may be destroyed by man for his settlement, agriculture, mining, industries, highway construction, dam building etc.

As a consequence, the species must adapt to the changes in the environment, move elsewhere or may succumb to predation, starvation or disease and eventually die. Several rare butterfly species are facing extinction due to habitat destruction in the Western Ghats. Of the 370 butterfly species available in the Ghats, around 70 are at the brink of extinction.

**Habitat fragmentation:**

Habitat fragmentation may be defined as an "unnatural detaching or separation of expansive tracts of habitats into spatially segregated fragments" that are too limited to maintain their different species for an infinite future.

This phenomenon was observed as early as 1885 when de Candolle noticed that 'the break-up of a landmass into smaller units would necessarily lead to the extinction or local extermination of one or more species and the differential preservation of others'.

Habitat fragmentation is one of the most serious causes of erosion of biodiversity. Fragmentation leads to artificially created 'terrestrial islands'. Such fragments experience microclimatic effects markedly different from those that existed in the large tracks of habitats before fragmentation. Air temperature at the edges of fragments can be significantly higher than that found in the interior; light can penetrate deep into the edge, thereby affecting the growth of existing species. Fragmentation promotes the migration and colonization of alien species. Such substantial and continuous colonization, profoundly affect the survival of nativespecies.

The most serious effect of fragmentation is segregation of larger populations of a species into more than one smaller population. There is considerable evidence that the number of speciesin a fragmented habitat will decrease over time, although the probable rates at which it will

happen are variable. In fact, actual data on rain forests show that forest fragments have lower species richness and fewer populations compared with continuous undisturbed forests.

An example of loss of biodiversity as the result of the fragmentation is that of the Western forest of Ecuador, which were largely undisturbed till 1960, where newly constructed networkof roads led to rapid human settlements and clearance of much of the forest area, have been fragmented into small patches of one to few square kilometers.

**Deforestation:**

Forest ecosystems contain as much as 80 percent of the world's terrestrial biodiversity andprovide wood fiber and biomass energy

as well as critical components of the global cycles of water, energy and nutrient. Forest ecosystems are being cleared and degraded in many parts of the world.

Current projections suggest that demandfor wood will roughly double over the next 50 years, which will make increasing use of sustainable forest practices more difficult. In addition to threats to biodiversity and potentialshortages in the supply of forest products, the degradation of forests represents an enormous potential source of green house gas emissions.

Forest ecosystems contain about three times the amount of carbon currently present in the atmosphere and about one-third of this carbon is stored above ground in trees and other vegetation and two-third is stored in the soil.

**Invasive Species:**

Invasive species are 'alien' or 'exotic' species which are introduced accidentally or intentionally by human. These species become established in their new environment and spread unchecked, threatening the local biodiversity. These invasive alien species have been identified as the second greatest threat to biodiversity after habitat loss.

- Invasion by exotic species

Prominent examples are the spread of the Peruvian thorny *Prosopis juliflorain in* the dry parts of northern India where it replaced native species such as *Acacia nilotica* and the spread of the South American flowering bush *Lantana camara* in the sub-Himalayan belt.

**Overexploitation for Commercialization:**

Over-exploitation of resources has coasted more environmental degradation than earning. For example; shrimp farming in India, Thailand, Ecuador and Indonesia results in Wetland destruction, pollution of coastal waters and degradation of coastal fisheries. Scientific studies have concluded that cost of environmental degradation resulting from shrimp farming was costing more than the earning through shrimp exports.

**Pollution:**

Pollution is a major threat to biodiversity, and one of the most difficult problems to overcome; Pollutants do not recognize international boundaries. For example, agricultural run-off, which contains a variety of fertilizers and pesticides, may seep into ground water and rivers before ending up in the ocean. Atmospheric pollutants drift with prevailing air currents and are deposited far from their original source.

**Global Climate Change:**

Many climatologists believe that the greenhouse effect is likely to raise world temperatures by about 2°C by 2030, meaning that sea levels will rise by around 30-50 cm by this time. Global warming, coupled with human population growth and accelerating rates of resource use will bring further losses in biological diversity. Vast areas of the world will be inundated causing loss of human life as wellas ecosystems.


- ecosystem encroachment(inundation of shoreline ecosystems & drowning of coral reefs from sea level rise, sand dune encroachment from desertification)
- changes in geochemical regimes (ocean acidification, changes in atmospheric CO2 affecting plant growth, loss of sediment leading to broad-scale subsidence)
- changes in temperature regimes (heat waves, cold spells, oceanic temperature changes,melting of glaciers/sea ice)
- changes in precipitation & hydrological regimes (droughts, rain timing, loss of snowcover, increased severity of floods)
- severe weather events (thunderstorms, tropical storms, hurricanes, cyclones, tornadoes, hailstorms, ice storms or blizzards, dust storms, erosion of beaches during storms)

**Population Growth and Over-consumption:**

From a population of one billion at the beginning of the 19th century, our species now numbers more than six billion people. Such rapid population growth has meant a rapid growth in the exploitation of natural resources— water, foods and minerals. Although there is evidence that our population growth rate is beginning to slow down, it is clear that the exploitation of natural resources is currently not sustainable. Added to this is the fact that 25 per cent of the population consumes about 75 per cent of the world's natural resources. This problem of over-consumption is one part of the broader issue of unsustainable use.

**Illegal Wildlife Trade:**

The international trade in wild plants and animals is enormous. Live animals are taken for the pet trade, or their parts exported for medicines or food. Plants are also taken from the wild for their horticultural or medicinal value.

**Species extinction:**

Extinction is a natural process. The geological record indicates that many hundreds of thousands of plant and animal species have disappeared over the eras as they have failed to adapt to changing conditions. Recent findings however indicate that the current rate of species extinction is at least a hundred to a thousand times higher than the natural rate.

**IUCN:**

The International Union for Conservation of Nature (IUCN; officially International Union for Conservation of Nature and Natural Resources) is an international organization working in thefield of nature conservation and sustainable use of natural resources. It is involved in data gathering and analysis, research, field projects, advocacy, and education. IUCN's mission is to"influence, encourage and assist societies throughout the world to conserve nature and to ensure that any use of natural resources is equitable and ecologically sustainable".

Over the past decades, IUCN has widened its focus beyond conservation ecology and now incorporates issues related to sustainable development in its projects. IUCN does not itself aim to mobilize the public in support of nature conservation. It tries to influence the actions of governments, business and other stakeholders by providing information and advice, and through building partnerships. The organization is best known to the wider public for compiling and publishing the IUCN Red List of Threatened Species, which assesses the conservation status of species worldwide.

IUCN has a membership of over 1400 governmental and non-governmental organizations. Some 16,000 scientists and experts participate in the work of IUCN commissions on avoluntary basis. It employs approximately 1000 full-time staff in more than 50 countries. Its headquarters are in Gland, Switzerland.

IUCN has observer and consultative status at the United Nations and plays a role in the implementation of several international conventions on nature conservation and biodiversity. It was involved in establishing the World Wide Fund for Nature and the World Conservation Monitoring Centre. In the past, IUCN has been criticized for placing the interests of nature over those of indigenous peoples. In recent years, its closer relations with the business sector have caused controversy.

IUCN was established in 1948. It was previously called the International Union for the Protection of Nature (1948–1956) and the World Conservation Union (1990–2008).

## Current work

### IUCN Programme 2017–2020

According to its website, IUCN works on the following themes: business, climate change, economics, ecosystems, environmental law, forest conservation, gender, global policy, marine and polar, protected areas, science and knowledge, social policy, species, water and world heritage.

IUCN works on the basis of four-year programs, determined by the membership. In the IUCN Programme for 2017–2020 conserving nature and biodiversity is linked to sustainable development and poverty reduction. IUCN states that it aims to have a solid factual base for its work and takes into account the knowledge held by indigenous groups and other traditionalusers of natural resources.

The IUCN Programme 2017–2020 identifies three priority areas:

1. Valuing and conserving nature.
2. Promoting and supporting effective and equitable governance of natural resources
3. Deploying Nature Based Solutions to address societal challenges including climate change,food security and economic and social development.

IUCN does not itself aim to directly mobilize the general public. Education has been part of IUCN's work program since the early days but the focus is on stakeholder involvement and strategic communication rather than mass-campaigns.

**Habitats and species**

IUCN runs field projects for habitat and species conservation around the world. It produces the IUCN Red List of Threatened Species and the IUCN Red List of Ecosystems. The IUCN Red List of Ecosystems is applicable at local, national, regional and global levels.

IUCN' stated goal is to expand the global network of national parks and other protected areas and promote good management of such areas. In particular, it focuses on greater protection of the oceans and marine habitats.

**Business partnerships**

IUCN has a growing program of partnerships with the corporate sector on a regional, national,and international level to promote sustainable use of natural resources.

**National and international policy**

On the national level, IUCN helps governments prepare national biodiversity policies. Internationally, IUCN provides advice to environmental conventions such as the Convention on Biological Diversity, CITES and the Framework Convention on Climate Change. It advises UNESCO on natural world heritage.

It has a formally accredited permanent observer mission to the United Nations.IUCN has official relations with the multiple other international bodies.

**IUCN in India:**

- India a mega diverse country accounts for 7-8% of all recorded species.
- Over 45,968 species of plants and 91,364 species of animals.
- of 34 globally identified biodiversity hotspots: The Himalayas, the Western Ghats, theNorth-East, and the Nicobar Islands in India.
- India became a State Member of IUCN in 1969, through the Ministry of EnvironmentForest and Climate Change (MoEFCC).
- The IUCN India Country Office was established in 2007 in New Delhi.

**Red data list:**

- **The IUCN Red list of threatened species is also known as the IUCN Red list orRed data list.**
- IUCN Red list was founded in **1964**, is the world's most comprehensive inventory ofthe global conservation status of biological species. The IUCN is the world's main authority on the conservation status of species.
- A series of regional red lists are produced by countries or organizations, which assessthe risk of extinction
- The IUCN Red list is set upon precise criteria to evaluate the extinction risk ofthousands of species and subspecies.

**According to IUCN (1996), the formally stated goals of the Red List are**

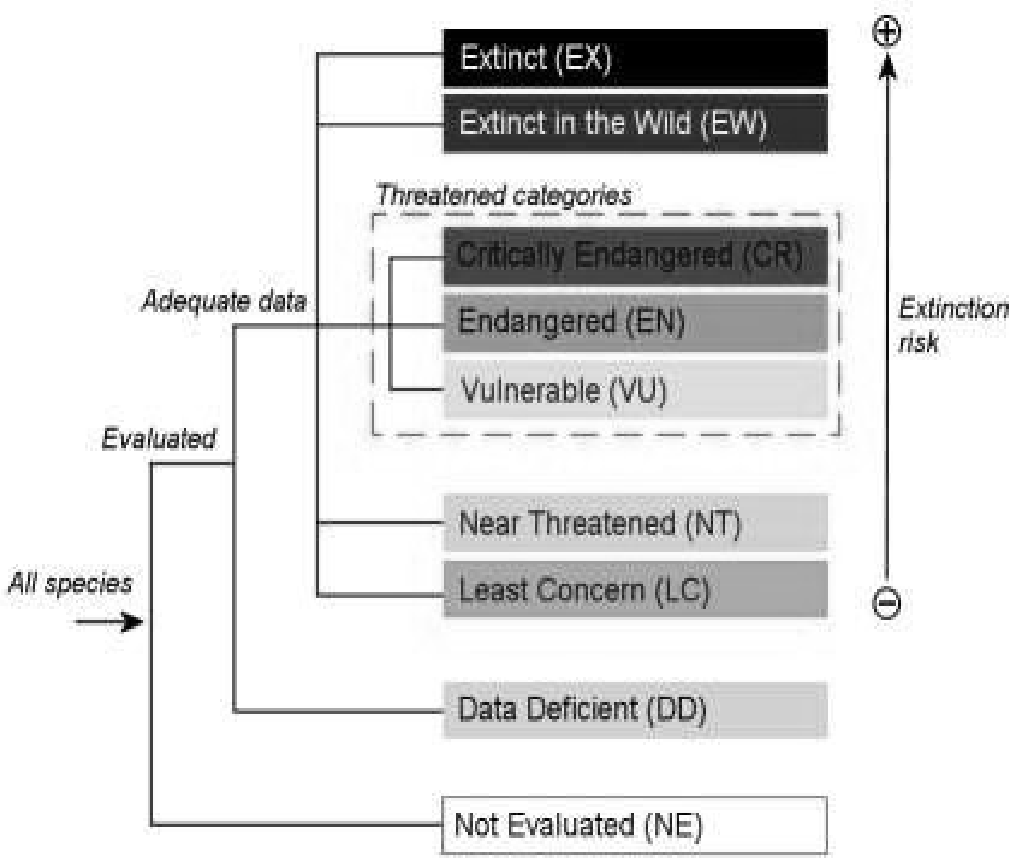
(1) To provide scientifically based information on the status of species and subspecies at aglobal level.
(2) To draw attention toward the importance of threatened biodiversity.
(3) To provide information to guide actions to conserve biological diversity.

| **Category** | **Total no. of Species in world** |
|---|---|
| Extinct | 868 |
| Extinct in the wild | 78 |

| | |
|---|---|
| Critically endangered | 5176 |
| Endangered | 7705 |
| Vulnerable | 11654 |
| Near threatened | 4406 |
| Least concern | 36952 |
| **Total** | **82065** |

**IUCN Red list Categories:**

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



**Extinct:**

- ❖ A species is Extinct when the last existing member dies.
- ❖ The moment of extinction is generally considered to be the death of the last individualof the species.
- ❖ Total 868 species Extinct in the world.

**Extinct in the Wild:**

- ❖ "Extinct in the Wild" (EW) Species listed under this status by IUCN are not known to have any living specimens in the wild, and are maintained only in zoos or other artificial environments.
- ❖ When possible, modern zoological institutions try to maintain a viable population for species preservation and possible future reintroduction to the wild, through use of carefully planned breeding programs.
- ❖ Total **78** species Extinct in the wild in world.

**Critically endangered:**

- ❖ A Critically endangered (cr) species is one which has been categorized by the IUCN as
  **facing a very high risk of extinction in the wild.**
- ❖ Total **5176** species critically endangered in the world.
- ❖ As of September 2016, the IUCN lists **455** Critically endangered fish species
- ❖ **The important criteria are :**
  (a) an observed estimated, inferred or suspected reduction of at least **80 %** over atleast **10 year or 3 generation**.
  (b) population estimated to number less than **250** mature individuals.

**Endangered:**

- ❖ A taxon is endangered when it is not critically endangered but it is facing a very **highrisk of extinction in the wild in a near future.**
- ❖ **7705** species are endangered worldwide.

**The important criteria are:**

(a) an observed, estimated , inferred or suspected reduction of at least **50 %** over at least10 years or 3 generation.

(b) population estimated to number less than **2,500** mature individuals

**Vulnerable:**

- A taxon is vulnerable when it is not critically endangered or endangered but is facing ahigh risk of **extinction in the wild in the medium term future .**
- Total 11654 species are vulnerable worldwide.
- **The important criteria are :**
  (a) an observed ,estimated, inferred, or suspected reduction of at least **20 %** over atleast 10 year or 3 generation.
  (b) population estimated to number less than 10,000 mature individual.

**Rare:**

Taxa which are not presently endangered or vulnerable but can become Rare because of smallpopulation usually located in restricted scattered over a more extensive range.

**Lower Risk:**

Taxa included in the lower risk category can be separated in to three sub categories :

1) **Conservation dependent ( lr-cd )** : Taxa which would qualify for threatened categorieswithin five year it is known as conservation dependent.
2) **Near threatened (lr-nt)** : Taxa which do not qualify for conservation dependent, butwhich are close to qualifying for vulnerable.
3) **Least concern (lr-lc )** : Taxa which do not qualify for conservation dependent or nearthreatened.

**Data deficient:**

- ❖ Known, but appropriate data on abundance and /or distribution is lacking.
- ❖ Listing a taxon is data deficient (dd) when there is inadequate information to make a direct or indirect assessment of its of extinction based on its distribution and / or population status.

**Not evaluated (NE):** A taxon is not evaluated (ne), when it has not yet been assessed againstthe criteria.

## 5. Conservation: Types of conservation - in-situ conservation: Biosphere Reserve, Wildlife Sanctuaries, National Parks, World Heritage Sites; Concept and types of Protected Areas Networks; ex-situ conservation: principles, methods, definition, aims and activities of W.W.F., Red Data Book, MAB, CITES, Role of Botanic Gardens and Gene Banks.

**Conservation:**

Conservation is the protection, preservation, management, or restoration of. There is an urgent need, not only to manage and conserve the biotic wealth, but also restore the degraded ecosystems.

Humans have been directly or indirectly dependent on biodiversity for sustenance to a considerable extent. However, increasing population pressure and developmental activities have led to large scale depletion of the natural resources.

Conservation is the protection, preservation, management, or restoration of wildlife and natural resources such as forests and water. Through the conservation of biodiversity and the survival of many species and habitats which are threatened due to human activities can be ensured. There is an urgent need, not only to manage and conserve the biotic wealth, but also restore the degraded ecosystems.

**Mainly the conservation of biodiversity has three basic objectives:**

(a) To maintain essential ecological processes and life supporting systems.

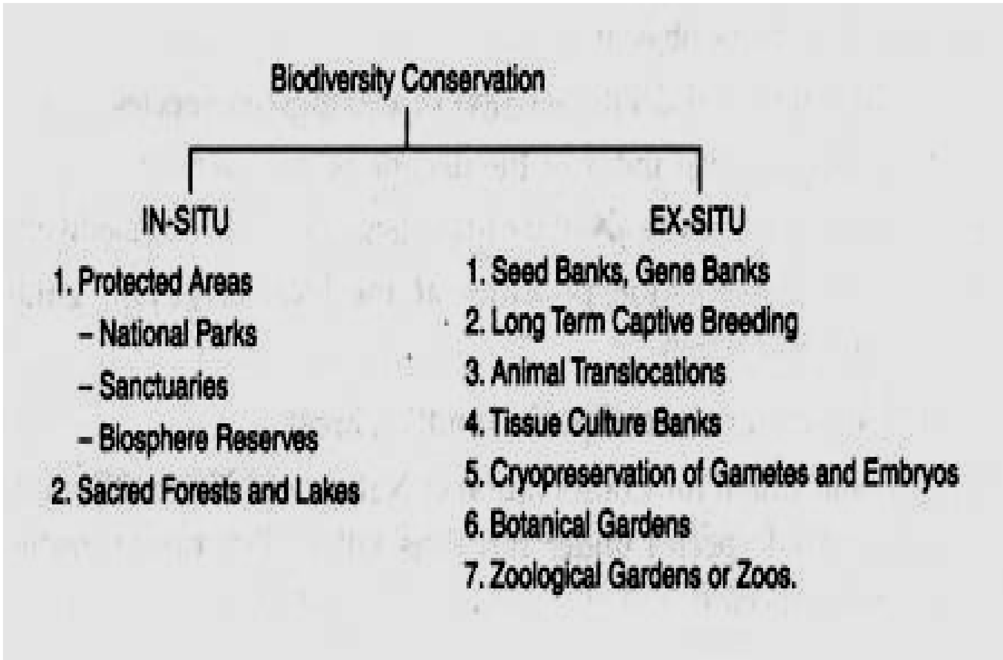
(b) To preserve the diversity of species.

(c) To make sustainable utilisation of species and ecosystems.

**Types of Conservation:**

Conservation can broadly be divided into two types:

1. In-situ conservation
2. Ex-situ conservation




**1. In-Situ Conservation Strategies:**

In-situ or on site conservation is conservation of wild animals and plants in their natural habitat. The aim of in-situ conservation is to allow the population to maintain or perpetuate itself within the community environment, to which it is adapted. In-situ conservation is the ideal method of conserving wild plant genetic resources. In-situ conservation of plant genetic resources presents a number of advantages as compared to ex-situ conservation.

**Advantages of In-Situ Conservation of Plant Resources:**

a. It enables the conservation of a large range of potentially interesting alleles.
b. This method is especially suitable for species, which cannot be established or regeneratedoutside the natural habitats.
c. This method allows natural evolution to continue because of the existence of variation.

d. It facilitates research on species in their natural habitats.
e. It assures protection of other species that are dependent on the species under consideration.

**Methods of In-Situ Conservation:**

In-situ conservation is done by providing protection to biodiversity rich areas through a network of protected areas. In India, the protected areas are of the following kinds – national parks, wildlife sanctuaries, biosphere reserves and ecologically fragile and sensitive areas. A protected area network of 85 national parks and 448 wildlife sanctuaries has been created. The results of this network have been significant in restoring viable population of large mammals such as tiger, lion, rhinoceros, crocodiles and elephants.

Eco-development programmes involving local communities have been initiated recently for sustained conservation of ecosystems. The economic needs of the local communities are takencare under this programme through provision of alternative sources of income and a steady availability of forest and related products.

Programmes have also been launched for scientific management and wise use of wetlands, mangroves and coral reef ecosystems. Twenty-one wetlands and mangrove areas and four coral reef areas have been identified for intensive conservation and management purposes.

Six significant wetlands of India have been declared as 'Ramsar Sites' under the Ramsar Convention. Under the World Heritage Convention, five natural sites have been declared as 'World Heritage Sites'.

In India following types of natural habitats are being maintained:

1. National parks
2. Wildlife sanctuaries
3. Biosphere reserves

INDIA has over 600 protected areas, which includes over 90 national parks, over 500 animalsanctuaries and 15 biosphere reserves.

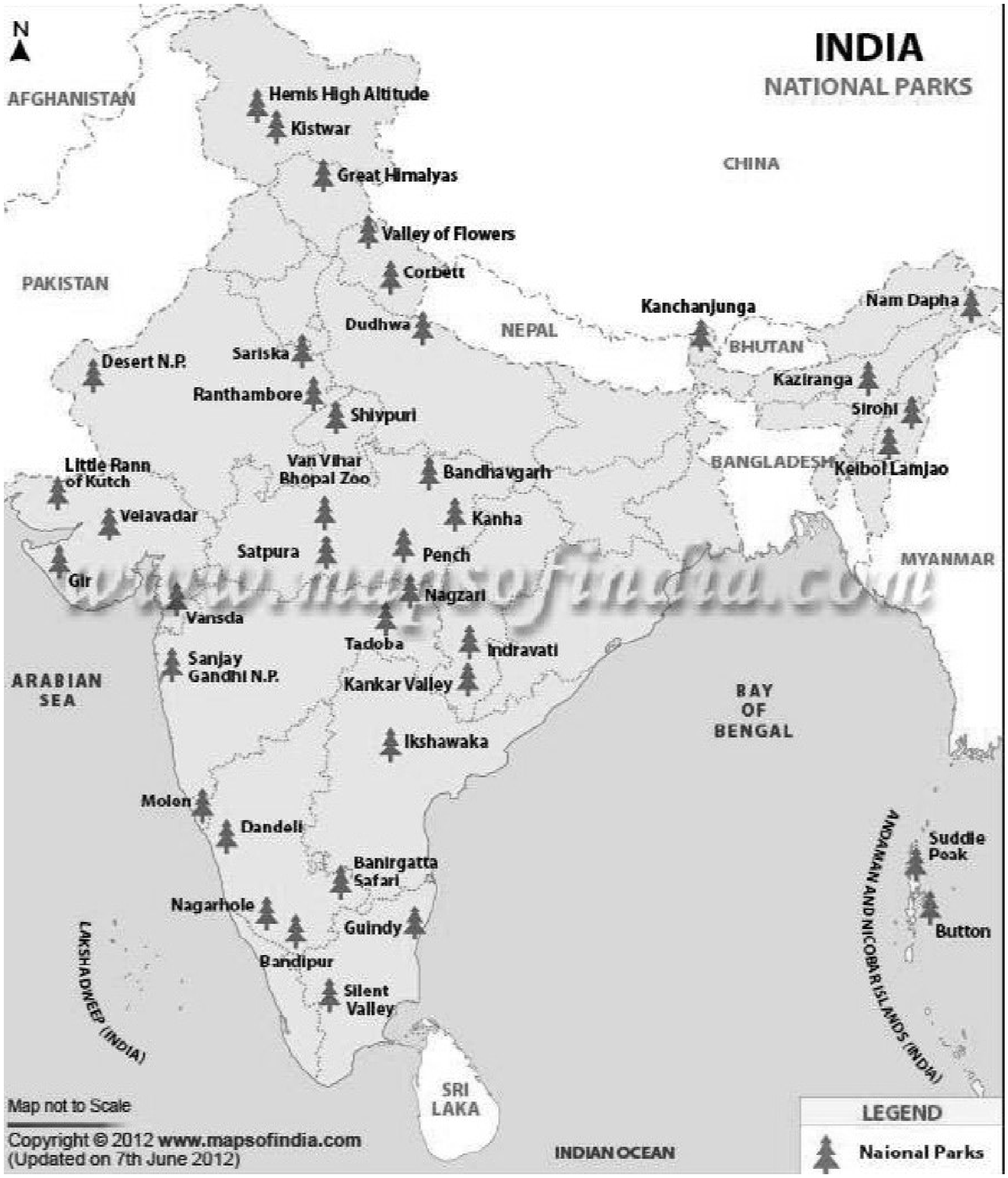
**National Park:**

A national park is a reserve of land, usually owned by a national government. It is a tract of land, which is declared public property to preserve and develop for the purpose of recreation and culture. It is protected from human development activities and pollution. National parks are protected areas of IUCN category II.

- There are 10 existing national parks in India covering an area of 38,024.10 km2,which is 1.16% of the geographical area of the country.
- Yellowstone National Park in California was established as the world's first protectedarea.
- The first national park in India was Hailey National Park, now known as Jim CorbettNational Park, established in the year 1935.
- Largest National Park-Northeast Greenland National park,197

| **Sl. No.** | **Name** | **State** | **Established** | **Area (inkm$^2$)** |
|---|---|---|---|---|
| 1. | Corbett National Park | Uttarakhand | 1921 | 1318.5 |
| 2. | Dudhwa National Park | Uttar Pradesh | 1977 | 490.29 |
| 3. | Gir Nationa lPark | Gujarat | 1965 | 258.71 |
| 4. | Kanha National Park | Madhy a Prades h | 1955 | 940 |

| | | | | |
|---|---|---|---|---|
| 5. | Kanger Ghati National Park(Kanger Valley) | Chhattisgarh | 1982 | 200 |
| 6. | Kaziranga National Park | Assam | 1974 | 471.71 |
| 7. | Nanda Devi National Park | Uttarakhand | 1982 | 630.33 |
| 8. | Sariska National Park | Rajasthan | 1955 | 866 |
| 9. | Silent Valley National Park | Kerala | 1980 | 237 |
| 10. | Sundarbans National Park | West Bengal | 1984 | 1330.12 |




**Biosphere reserves:**

Biosphere reserves are a special category of protected areas of land and/or coastal environments, wherein people are an integral component of the system.

The biosphere reserves are representative examples of natural biomes and contain unique biological communities.

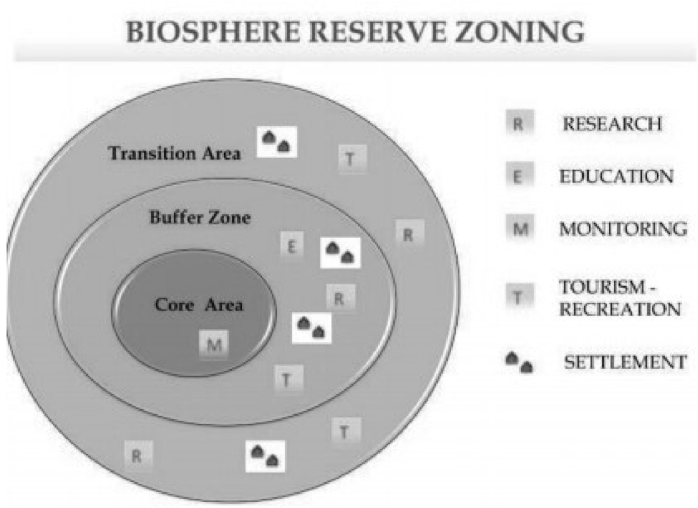
The concept of Biosphere Reserves was launched in 1975 as a, part of UNESCO's 'Man and Biosphere Programme, dealing with the conservation of ecosystems and the genetic resources contained therein.

Till May 2002, there were 408 biosphere reserves dispersed in 94 countries.

In India, thirteen biodiversity rich areas have been designated as Biosphere Reserves applyingthe diversity and genetic integrity of plants, animals and microorganisms.

The biosphere reserve has concentric areas zoned for different use.

a. The **core zone** is the innermost zone devoted to preserve biodiversity with no human interference.
b. Around the core zone there is the **buffer zone** in which some settlement and resource use is allowed. In this area, variety of educational programmes and research activities are carried out, such as identification of endangered species, artificial propagation of species, and application of tissue culture techniques to enable rapid multiplication of threatened species.
c. The outermost zone is the **transition zone** wheresustainable development activities are permitted. This is an area of interaction between the biosphere reserve management and the local people. Here activities such as forestry, recreation, cropping, etc. are permitted.




These reserves aim at conservingthe biological diversity and genetic integrity of plants, animals and microorganisms in their totality as part of the natural ecosystems.

There are approximately 400 biosphere reserves in 94 countries.

The list of biosphere reservesin India is given in Table 6.

Table 6 List of biosphere reserves in India.

| S. No. | Reserve | Location |
|---|---|---|
| 1. | Great Nicobar | Andaman and Nicobar Islands |
| 2. | Gulf of Mannar | Tamil Nadu |
| 3. | Kanha | Madhya Pradesh |
| 4. | Kaziranga | Assam |
| 5. | Manas | Assam |
| 6. | Namdapha | Arunachal Pradesh |
| 7. | Nanda Devi | Uttar Pradesh |
| 8. | Niligris | Tamil Nadu, Kerala and Karnataka |
| 9. | Nokrek Tura | Meghalaya |
| 10. | Rann of Kutch | Gujarat |
| 11. | Sunderbans | West Bengal |
| 12. | Thar Desert | Rajasthan |
| 13. | Valley of flowers | Uttar Pradesh |

**The main functions of biosphere reserves are:**

**(i) Conservation:**

To conserve the ecosystems, a biosphere reserve programme is being implemented, for example, conservation of landscapes, species and genetic resources. It also encourages traditional resource use.

**(ii) Eco-Development:**

The concept of eco-development integrates the ecological and economic parameters for sustained conservation of ecosystems by involving the local people with the maintenance of earmarked regions. Biosphere reserves are also used to promote economic development which is culturally, socially and ecologically sustainable.

**(iii) Scientific Research Programme:**

Programmes have also been launched for scientific management and wise use of fragile ecosystem. Specific programmes for management and conservation of wetlands, mangroves and coral reef systems are also being implemented.

Under this programme, 21 wetlands, 15 mangrove areas and 4 coral reef areas have been identified for management. National and sub-national level committees oversee and guide these programmes to ensure strong policy and strategic support.

**Wildlife Sanctuaries:**

A sanctuary is a protected area which is reserved for the conservation of only animals and human activities like harvesting of timber, collecting minor forest products and private ownership rights are allowed as long as they do not interfere with well-being of animals. Boundaries of sanctuaries are not well defined and controlled biotic interference is permitted, e.g., tourist activity.

**Wildlife sanctuaries of India**

- IUCN category IV
- There are 515 wildlife sanctuaries in India
- 41 tiger reserves, governed by Project Tiger
- Largest sanctuary: Nagarjun sagar - srisailam tiger reserve (A.P,Telengana)

| S.No. | Name | State | Established | Area (in $km^2$) |
|---|---|---|---|---|
| 1. | Ghana Bird Sanctuary | Rajasthan | 1982 | 28.73 |
| 2. | Hazaribag Wildlife Sanctuary | Jharkhand | 1954 | 183.89 |
| 3. | Mudumalai Wildlife Sanctuary | Tamil Nadu | 1940 | 321.55 |
| 4. | Jaldapara Wildlife Sanctuary | West Bengal | 2012 | 216 |
| 5. | Mount Abu Wildlife Sanctuary | Rajasthan | 1960 | 288.84 |
| 6. | Anamalai Wildlife Sanctuary (Indira Gandhi Wildlife Sanctuary and National Park) | Tamil Nadu | 1989 | 117.10 |


**World Heritage Site:**

A World Heritage Site is a landmark or area which is chosen by the **United Nations Educational, Scientific and Cultural Organisation (UNESCO)** as having cultural, historical, scientific or other form of significance, and is legally protected by international treaties. The sites are judged important to the collective interests of humanity.

To be selected, a World Heritage Site must be an already-classified landmark, unique in some respect as a geographically and historically identifiable place having special cultural or physical significance (such as an ancient ruin or historical structure, building, city, complex, desert, forest, island, lake, monument, mountain, or wilderness area). It may signify a remarkable accomplishment of humanity, and serve as evidence of our intellectual history on the planet.

The sites are intended for practical conservation for posterity, which otherwise would be subject to risk from human or animal trespassing, unmonitored/uncontrolled/unrestricted access, or threat from local administrative negligence. Sites are demarcated by UNESCO as protected zones. The list is maintained by the international World Heritage Program administered by the UNESCO World Heritage Committee, composed of 21 "states parties" that are elected by their General Assembly.

The programme catalogues, names, and conserves sites of outstanding cultural or natural importance to the common culture and heritage of humanity. Under certain conditions, listed sites can obtain funds from the World Heritage Fund. The program began with the Convention Concerning the Protection of the World's Cultural and Natural Heritage, which was adopted by the General Conference of UNESCO on 16 November 1972. Since then, 193 state parties have ratified the convention, making it one of the most widely recognized international agreements and the world's most popular cultural program.

As of July 2019, a total of 1,121 World Heritage Sites (869 cultural, 213 natural, and 39 mixed properties) exist across 167 countries. China and Italy, both with 55 sites, have themost of any country, followed by Spain (48), Germany (46), France (45), India (38), and Mexico (35).

**World Heritage Sites in India:**

According to UNESCO World Heritage Sites located in India are 37, as of June 2018, thesixth most of any country.

Some e.g.: Ajanta cave, Maharastra; Agra Fort, Uttar Pradesh, Taj Mahal, Uttar Pradesh.

**Ramsar Sites:**

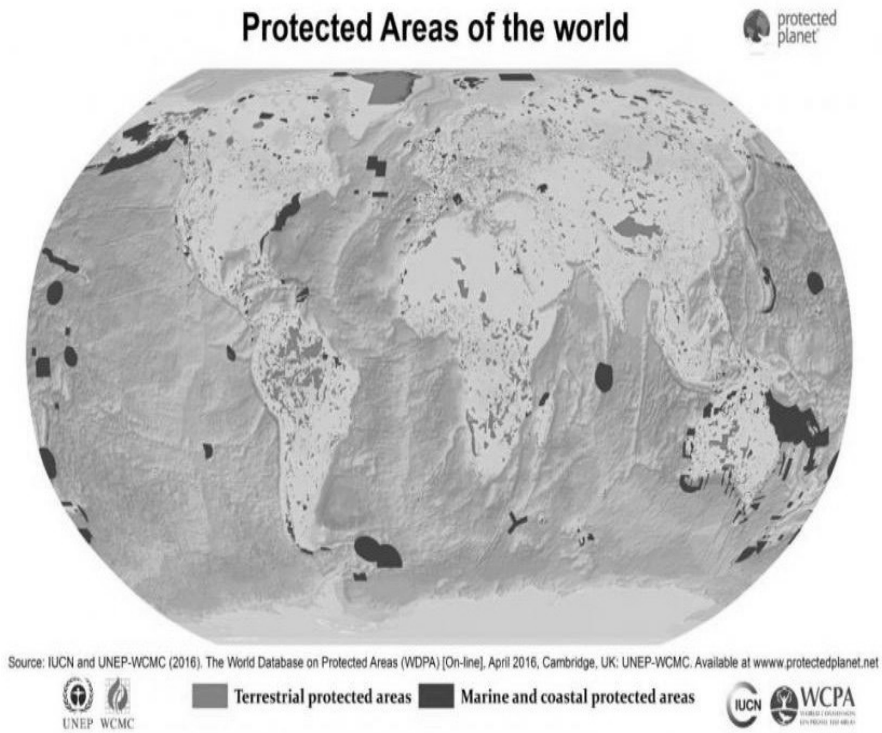
Six internationally significant wetlands of India have been declared as Ramsar Sites under the Ramsar Convention. To focus attention on urban wetlands threatened by pollution and other anthropogenic activities, state Governments were requested to identify lakes that could be include the National Lake Conservation Plan (NLCP).

**Protected area:**

A clearly defined geographical space, recognised, dedicated and managed through local or other effective means,to achieve the long term conservation of nature with associated ecosystem series and cultural values. **:(IUCN World Commission,2008)**

Protected areas – national parks, wilderness areas, community conserved areas, nature reserves and so on – are a mainstay of biodiversity conservation, while also contributing to people's livelihoods, particularly at the local level. Protected areas are at the core of efforts towards conserving nature and the services it provides us – food, clean water supply, medicines and protection from the impacts of natural disasters. Their role in helping mitigate and adapt to climate change is also increasingly recognized; it has been estimated that the global network of protected areas stores at least 15% of terrestrial carbon.

Helping countries and communities designate and manage systems of protected areas on land and in the oceans, is one of IUCN's main areas of expertise. Together with species conservation, this has been a key focus of attention of IUCN's work and of a vast majority of IUCN Member organizations. Effectively managed systems of protected areas have been recognized as critical instruments in achieving the objectives of the Convention on Biological Diversity and the Sustainable Development Goals.




**IUCN Protected Area Management Categories:**

Through its World Commission on Protected Areas (WCPA), the IUCN has developed six Protected Area Management Categories that define protected areas according to their management objectives, which are internationally recognised by various national governments and the United Nations .The categories provide international standards for defining protected areas and encourage conservation planning according to their management aims.

**IUCN Protected Area Management Categories:**

Category Ia — Strict Nature Reserve Category Ib — Wilderness Area Category II — National Park

Category III — Natural Monument or Feature Category IV — Habitat/Species Management AreaCategory V — Protected Landscape/Seascape

Category VI – Protected Area with sustainable use of natural resources

**Protected area of India**

India is one of the 17 mega diverse countries of the world.India is home to World's largest wild tiger population and has got unique assemblage of globally important endangered specieslike Asiatic lion,asian elephant,one horned rhinoceros,gangetic river dolphin,snow leopard,kashmir stag,gharial,great indian bustard etc.

A National Board for Wildlife (NBWL),chaired by the PM of India provides for policy frameworkfor wildlife conservation in the country. The National Wildlife Action Plan(2002- 2016) has been adopted;emphasizing the peoples' participation & their support for wildlife conservation.

**The main benefits of protected areas are:**

a. To maintain viable populations of all native species and subspecies.

b. To maintain the number and distribution of communities and habitats. Conservation of thegenetic diversity of all the existing species.

c. To prevent human caused introductions of alien species.

d. To make it possible for species and habitats and shift in response to environmental changes.

**Ex-situ conservation:**

Ex-situ conservation literally means, "off-site conservation". It is the process of protecting an endangered species of plant or animal by removing part of the population from a threatened habitat and placing it in a new location, which may be a wild area or within the care of humans. While ex-situ conservation comprises some of the oldest and best known conservation methods, it also involves newer, sometimes controversial laboratory methods.

Ex situ conservation, using sample populations, is done through establishment of gene banks, whih include genetic resources centres, zoo's, botanical gardens, cultue collections etc.

**Advantanges of Ex situ conservation:**

The conservation of biodiversity can be achieved through an integrated approach balancing in situ and ex situ conservation strategies. The preservation of species in situ offers all the advantages of allowing natural selection to act, which cannot be recreated ex situ. The maintenance of viable and self-sustainable populations of wild species in their natural state represents the ultimate goal, but habitat destruction is inevitable and endangered species need to be preserved before they become extinct. Ex situ conservation provide the opportunity to study the biology of, and understand the threats to, endangered species in order to eventually consider successful species recovery programmes, which would include restoration and reintroduction. It also has the advantage of preserving plant material and making it available for research purposes, without damaging the natural populations. Their conservation ex situ is therefore complementary to in situ conservation and can act as an "insurance policy" when species are threatened in their natural habitats It is the process of protecting an endangered species of plant or animal by removing part of the population from a threatened habitat and placing it in a new location, which may be a wild area or within the care of humans.

**Ex-situ conservation has several purposes:**

- Rescue threatened germplasm.
- Produce material for conservation biology research.
- Bulk up germplasm for storage in various forms of ex situ facility.
- Supply material for various purposes to remove or reduce pressure from wildcollecting.
- Grow those species with recalcitrant seeds that cannot be maintained in a seed store.
- Make available material for conservation education and display.
- Produce material for reintroduction, reinforcement, habitat restoration and management.

Some important areas under these conservation are:

**Gene Banks:**

Plant genetic resources gene banks store, maintain and reproduce living samples of the world's huge diversity of crop varieties and their wild relatives. They ensure that the varieties and landraces of the crops and their wild relatives that underpin our food supply are both secure in the long term and available for use by farmers, plant breeders and researchers.

Gene banks conserve genetic resources. The most fundamental activity in a gene bank is to treat a new sample in a way that will prolong its viability as long as possible while ensuring its quality. The samples (or accessions as they are called) are monitored to ensure that they are not losing viability. A cornerstone of gene bank operations is the reproduction-called regeneration-of its plant material. Plant samples must periodically be grown out, regenerated, and new seed harvested because, even under the best of conservation conditions, samples will eventually die.

To conserve and regenerate genetic resources, gene banks first must collect genetic resources. But gene banks aren't built just to conserve genetic resources; they are intended to ensure that these resources are used, whether it is in farmers' fields, breeding programmes or in research institutions. This means making sure the collections are properly characterized and documented; and that the documentation is available to those who need it. The information systems used by gene banks are becoming increasingly important tools for researchers and breeders seeking data on the distribution of crops and their wild relatives.

**Purpose of Gene Banks**

- Physical facilities for maintaining collections of live plant materials – domesticated cultivated plants – wild plant species (crop wild relatives and other wild plant species useful for food and agriculture and other end uses) – entire plants, seeds, pollen, embryos, meristems, cells, or DNA, depending on the biology of the species
- It is a facility for maintaining crop diversity.
- Usually this diversity is in the form of seeds, stored and conserved in a frozen state.
- Some gene banks use normal household freezers for this purpose.
- The ideal temperature is between -10and -20.
- Each different type is stored in its own container.

Such as a bottle, a can or a sealed aluminum foil package.

**Activities in Gene Bank**

The main activities in the development and management of a gene bank include:

- **Collecting and Acquisition** – assembling the collection

- **Processing –** assessing the quantity, viability, health of samples
- and preparation for storage
- **Storage –** in a cold store, laboratory or in the field
- **Regeneration and Multiplication –** periodically rejuvenating and increasing thematerial
- **Characterization and Evaluation**
- **Documentation, Inventory –** maintaining and making available detailed records oneach sample
- **Distribution –** of clean, disease-free seeds, or other planting material, to requestors

**Seed Gene Bank:**

- A place where germplasm is conserved in the form of seeds is called seed gene bank.
- Seeds are very convenient for storage because they occupy smaller space than wholeplants.
- However, seeds of all crops cannot be stored at low temperature in the seed banks.
- The germplasm of only orthodox species can be conserved in seed banks.
- In the seed banks, there are three types of conservation, viz.
  1) Short term,
  2) Medium term and
  3) Long term.
- Base collections are conserved for long term (50 years or more) at 18 or 20°C.
- Active collections are stored for short term (3-5 years) at 5-10°C.

**Pollen Bank:**

Pollen preservation may be useful for base collections of species that do not produce orthodoxseeds.

- It requires little space but some cytoplasmic genes would be lost.
- Like seeds, pollen can be divided into desiccation tolerant and intolerant.

- However, information about storage characteristics of pollen from wild species is fragmentary, existing mainly for some crop relatives and for medicinal and forest species (Eberhart, Roos & Towill, 1991).

**DNA Bank:**

The creation of a network of DNA banks is ex situ conservation and more precisely germplasm collections can allow large quantities of genetic resources (genes, DNA) to be stored quickly and at low cost and could act as an insurance policy against rapid loss of the world's gene pool.

- It could be used in molecular phylogenetic and systematics of extinct taxa and genes can be distributed via the polypeptide chain reaction (PCR) using primers supplied by the users (Adams et al., 1994).
- DNA samples have been mainly used for bio-prospecting and assessment of biodiversity studies.
- Its use in conservation is limited as whole plants cannot be reconstituted from DNAbut the genetic material can be introduced to other genotypes for plant breeding and enhancement purposes.

**Botanical gardens:**

Botanical gardens and zoos are the most conventional methods of ex-situ conservation, all of which house whole, protected specimens for breeding and reintroduction into the wild when necessary and possible. These facilities provide not only housing and care for specimens of endangered species, but also have an educational value. They inform the public of the threatened status of endangered species and of those factors which cause the threat, with the hope of creating public interest in stopping and reversing those factors which jeopardize a species' survival in the first place. They are the most publicly visited ex-situ conservationsites.

The history of botanic gardens can be traced as far back as the Hanging Gardens of Babylon, built by Nebuchadnezzar in 570 BC as a gift to his wife. Early botanic gardens were designed mainly for the purpose of recreation. By the 16th Century, however, they had also become important centers for research. They promoted the study of taxonomy and became a focalpoint for the study of aromatic and medicinal plants.

More recently, they have taken on significant conservation responsibilities and they often have conservation facilities, such as seed banks and tissue culture units.

Botanical gardens hold living collections. Indeed botanical garden conservation could be considered as field gene bank or seed gene bank or both, depending on the conservation method being used. However, they tend to focus their conservation efforts on wild, ornamental, rare and endangered species. Most of the germplasm conserved in botanical gardens do not belong to the plant genetic resources for food and agriculture.

A botanic garden which wishes to start a small seed bank /gene bank would be advised to start with collecting germplasm that is very well documented from their living plant collection.This would allow them to experiment with a wide range of species and find suitable facilities and techniques for their particular needs. Once the set up is organised and functional, it would be advisable to collect accessions directly from the wild in order to distribute a wider genetic variability and to reduce the effect of domestication on the genetic make up of the accessions. Last two hundred years, efforts of botanic gardens in collecting plant material, and the greatefforts on crop germplasm collection during the 1970s and the 1980s, there are a large number of gene banks and germplasm collections around the world. According to the FAO and World Information & Early Warning System (WIEWS) database, it is estimated that there are now more than 2000 botanic gardens known around the world in over 150 countries. Together, they maintain more than 6 million accessions in their living collections and 142 million herbaria specimens in the botanic garden herbaria. 60% of the total numbers of accessions areknown to be stored in medium-term or long-term facilities, 8% in short-term facilities and 10% in field gene banks, in vitro and under cryopreservation. Clearly, seed storage is the predominant form of plant genetic resource conservation, accounting for about 90% of thetotal accessions held ex situ.

It is very difficult to give an estimate of the type of collections stored around the world as such information is known for only a third of the accessions in the WIEWS database. However, it has been estimated that 48% of all accessions are advanced cultivars or breeders' lines, while over a third are landraces or old cultivars and about 15% are wild or weedy plants or crop relatives.

***Some famous botanic gardens/ research centers/ institutes:***

**International**

1. **Royal Botanical Garden Kew, England :** Largest botanical garden in world and itsherbarium is also largest in world, having 6 million specimen.
2. **CIAT:** International Center for Tropical Agriculture located at Palmira, Columbia
3. **ICARDA:** International Center for Agriculture Research in Dry Areas located at Allepo,Syria
4. **ICRISAT:** International Center for Agriculture Research for Semi Arid Tropics located atPatencheru, (Hyderabad) India.
5. **IRRI:** International Rice Research Institute located at Manila, Philippines.

**National**

1. **Indian Botanical Garden, Calcutta :** Largest Botanical Garden in India and its herbariumis largest in India, having 1 million specimen
2. **NBRI:** National Botanical Research Institute located at Lucknow (UP) formally known asNational Botanical Garden.
3. **BSI:** Botanical Survey of India started working in 1890 and is connected with plant exploration and writing up of regional floras and also preparation of flora of India.
4. **IARI:** Indian Agricultural Research Institute or Pusa Institute located at New Delhi. It wasinitially established at village Pusa in Darbhanga District of Bihar in 1905 under the name Imperial Agricultural Research Institute. After a severe earthquake, this institute wasshifted to New Delhi in 1936 under the same name. But after independence, it wasrenamed as Indian Agricultural Research Institute.
5. **FRI:** Forest Research Institute located at Dehradun (Uttarakhand), established in 1906 under name Imperial Forest Research Institute (IFRI), but after independence, name was changed to FI. This institute is connected with researchers on different aspects of forest trees and also provides training to forest officer.

**Royal Botanical Garden**


**Acharya Jagadish Chandra BoseBotanical Garden**

**Role of Botanical Garden:**

Many of the functions of botanical gardens have already been discussed in the sections above,which emphasise the scientific underpinning of botanical gardens with their focus on research, education and conservation. However, as multifaceted organisations, all sites have their own special interests. In a remarkable paper on the role of botanical gardens, Ferdinand Mueller (1825–1896), the director of the Royal Botanic Gardens, Melbourne (1852–1873), stated, "in all cases the objects [of a botanical garden] must be mainly scientific and predominantly instructive". He then detailed many of the objectives being pursued by the world's botanical gardens in the middle of the 19th century, when European gardens were at their height. Many of these are listed below to give a sense of the scope of botanical gardens' activities at that time, and the ways in which they differed from parks or what he called "public pleasure gardens".

- availability of plants for scientific research
- display of plant diversity in form and use
- display of plants of particular regions (including local)
- plants sometimes grown within their particular families
- plants grown for their seed or rarity
- major timber (American English: lumber) trees
- plants of economic significance

- glasshouse plants of different climates
- all plants accurately labelled
- records kept of plants and their performance
- catalogues of holdings published periodically
- research facilities utilising the living collections
- studies in plant taxonomy
- examples of different vegetation types
- student education
- a herbarium
- selection and introduction of ornamental and other plants to commerce
- studies of plant chemistry (phytochemistry)
- report on the effects of plants on livestock
- at least one collector maintained doing field work

Botanical gardens must find a compromise between the need for peace and seclusion, while atthe same time satisfying the public need for information and visitor services that include restaurants, information centres and sales areas that bring with them rubbish, noise, and hyperactivity. Attractive landscaping and planting design sometimes compete with scientific interests — with science now often taking second place. Some gardens are now heritage landscapes that are subject to constant demand for new exhibits and exemplary environmentalmanagement.

Many gardens now have plant shops selling flowers, herbs, and vegetable seedlings suitable for transplanting; many, like the UBC Botanical Garden and Centre for Plant Research andthe Chicago Botanic Garden, have plant-breeding programs and introduce new plants to the horticultural trade.

**Cryopreservation:**

In this system stability is imposed by ultra low temperature and storage is at, or close to -1960C using liquid Nitrogen (or the vapour immediately above it), as practical and convenient oxygen. At such temperature normal cellular chemical reactions do not occur as energy level are too low to allow sufficient molecular motion to complete the reaction. Water exists either in a crystalline or glassy state under these conditions and such high viscosity (> 1013 poises) that rates of diffusion are insignificant over time spans measured at least as decades. The majority of the chemical changes that might occur in a cell are therefore; effectively prevented and so the cell is stabilized the maximum extent that is practically possible.

Unfortunately, that is not to say that biological material successfully cooled to -1960C is in state of complete suspended animation. Certain type of chemical reaction can still occur at these temperatures, such as the formation of the free radicals and macromolecular damage due to ionizing radiation. The only real threat to genetic stability comes from such reactions, especially those that damage nucleic acids. Any damage that does occur will necessarily be cumulative as enzyme repair mechanisms are also totally inhibited at these low temperatures.

While there are as yet few quantitative data on genetic stability at ultra low temperature for higher organisms, studied by Ashwood, Smith and Grant (1977) indicate that to reach a D10 level (where D10 is the readiation dose resulting in 90% mortality of the population) a frozen cell population would have to be exposed to back ground radiation for some 32,000 years. It is also noteworthy that dimethyl sulphoxide, probably the most commonly used cryoprotectant in-vitro preservation and may aid in radiation damage.

The potential of conservation system for in-vitro material based upon cryogenic storage is therefore, clear and the technique has become relatively widely used.

**Field Gene banks:**

Field gene banks or living collections are the main conservation strategy for long-lived perennials, recalcitrant species and vegetatively propagated species. Their main limitation is that they take a great deal of space and are difficult to maintain and protect from natural disasters. They are susceptible to the spread of diseases and may suffer from neglect. Furthermore, out-breeders require controlled pollination for regeneration from seed. In many circumstances they are the only available option for the conservation of important germplasm. When displayed, the plants have an important educational value and can easily be accessedfor research purposes.

The conservation of germplasm in field gene banks involves the collecting of materials and planting in the orchard or field in another location. Field gene banks have traditionally been used for perennial plants, including:

- Species producing recalcitrant seeds;
- Species producing little or no seeds;
- Species that are preferably stored as clonal material; and
- Species that have a long life cycle to generate breeding and/or planting material.

Field gene banks are commonly used for such species as cocoa, rubber, coconut, coffee, sugarcane, banana, tuber crops, tropical and temperate fruits, vegetatively propagated crops, such as wild onion and garlic, and forage grasses.

**Tissue culture bank:**

Tissue culture is a technique in which fragments of plants are cultured and grown in a laboratory. Many times the organs are also used for tissue culture. The media used for the growth of the culture is broth and agar.

This technique is also known as micropropagation. It has proved beneficial for the production of disease-free plants and increase plant yield in developing countries. It only requires a sterile workplace, greenhouse, trained manpower, and a nursery.

Oil palm, banana, eggplant, pineapple, rubber tree, tomato, sweet potato have been produced by tissue culture in the developing countries.Cryopreservation of disease free meristems is very helpful. Long term culture of excised rootsand shoots are maintained. Meristem culture is very popular in plant propagation as it's avirus and disease free method of multiplication.

**Captive breeding:**

Captive breeding is the process of maintaining plants or animals in controlled environments, such as wildlife reserves, zoos, botanic gardens, and other conservation facilities. It is sometimes employed to help species that are being threatened by human activities such as habitat loss, fragmentation, over hunting or fishing, pollution, predation, disease, and parasitism. In some cases a captive breeding program can save a species from extinction, but for success, breeders must consider many factors—including genetic, ecological, behavioral, and ethical issues. Most successful attempts involve the cooperation and coordination ofmany institutions.

**Long term captive breeding:**

The method involves capture, maintenance and captive breeding on long term basis of individuals of the endangered species which have lost their habitat permanently or certain highly unfavorable conditions are present in their habitat.

**Animal Translocation:**

Release of animals in a new locality which come from anywhere else. Translocation is carried in following cases:

1. When a species on which an animal is dependent becomes rare.
2. When a species is endemic or restricted to a particular area.
3. Due to habit destruction and unfavorable environment conditions.
4. Increase in population in an area.

**Zoological Gardens:**

In zoos wild animals are maintained in captivity and conservation of wild animals (rare, endangered species). The oldest zoo, the Schonbrumm zoo which exists today also, was established in VIENNA in 1759 In India, the 1st zoo came into existence at BARRACKPORE in 1800. In world there are about 800 zoos. Such zoos have about 3000 species of vertebrates. Some zoos have undertaken captive breeding programmes.

**7 major organization involved in consrvation of biodiversity:**

- ❖ **IUCN** (International Union for Conservation of Nature and Natural Resources)
- ❖ **CITES** (Convention on International Trade in Endangered Species of Wild Fauna andFlora, also known as the Washington Convention)
- ❖ **SSC** (Species Survival Commission )
- ❖ **CBD** (Convention on Biological Diversity )

- ❖ **TRAFFICS** (Trade Records Analysis of Flora and Fauna in Commerce)
- ❖ **WWF** (World Wide Fund for Nature)
- ❖ **WCMC** (World Conservation Monitoring Centre)

**WWF (World Wide Fund for Nature):**

The World Wide Fund for Nature (WWF) is an international non-governmental organization founded in 1961, working in the field of the wilderness preservation, and the reduction of human impact on the environment. It was formerly named the World Wildlife Fund, which remains its official name in Canada and the United States.

WWF is the world's largest conservation organization with over five million supporters worldwide, working in more than 100 countries, supporting around 1,300 conservation and environmental projects. They have invested over $1 billion in more than 12,000 conservation initiatives since 1995. WWF is a foundation with 55% of funding from individuals and bequests, 19% from government sources (such as the World Bank, DFID, USAID) and 8% from corporations in 2014.

WWF aims to "stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature." The Living Planet Report is published every two years by WWF since 1998; it is based on a Living Planet Index and ecological footprint calculation. In addition, WWF has launched several notable worldwide campaigns including Earth Hour and Debt-for-Nature Swap, and its current work is organized around these six areas: food, climate, freshwater, wildlife, forests, and oceans.

**LOGO**

WWF

**WWF's giant panda logo originated from a panda named *Chi Chi* that had been transferred from Beijing Zoo to London Zoo in 1958**

WWF has received criticism for its alleged corporate ties. It has also been accused of supporting paramilitary groups tasked with stopping poaching who are responsible for numerous human rights abuses.

Being famous as the onlypanda residingin the Western world at that time,its uniquely recognisable physical features and status as an endangered species were seen as ideal to serve the organization's need for a strong recognisable symbol that would overcome all language barriers.

**Who works with WWF?**

In carrying out its work, WWF cooperates with many partners, including UN organizations, IUCN, and development agencies such as USAID and the World Bank. WWF also workswith business & industry partners.

**WWF's mission:**

- WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature by,
- Conserving the world's biological diversity.
- Ensuring that the use of renewable natural resources is sustainable.
- Promoting the reduction of pollution and wasteful consumption.
- WWF focuses their efforts at multiple levels, starting with wildlife, habitats and local communities and expanding up through governments and global networks.

**What does WWF do?**

WWF's mission is to stop the degradation of our planet's natural environment, and build afuture in which humans live in harmony with nature.

In order to achieve this mission, WWF focuses its efforts on two broad areas:

- Biodiversity
- Footprint

The first is to ensure that the earth's web of life - biodiversity - stays healthy and vibrant for generations to come. We are strategically focusing on conserving critical places and critical species that are particularly important for the conservation of our earth's rich biodiversity.

The second, is to reduce the negative impacts of human activity - ourecological footprint. We are working to ensure that the natural resources required for life -land, water, air - aremanaged sustainably and equitably.

**2050 Biodiversity Goal**

By 2050, the integrity of the most outstanding natural places on Earth is conserved, contributing to a more secure and sustainable future for all

**2050 Footprint Goal**

By 2050, humanity's global footprint stays within the Earth's capacity to sustain life and the natural resources of our planet are shared equitably.

**Man and the Biosphere Programme (MAB):**

Man and the Biosphere Programme (MAB) is an intergovernmental scientific programme, launched in 1971 by UNESCO, which aims to establish a scientific basis for the improvement of relationships between people and their environments.

MAB's work engages fully with the international development agenda—specially with the Sustainable Development Goals and the Post 2015 Development Agenda—and addresses challenges linked to scientific, environmental, societal and development issues in diverse ecosystems; from mountain regions to marine, coastal and island areas; from tropical foreststo drylands and urban areas. MAB combines the natural and social sciences, economics and education to improve human livelihoods and the equitable sharing of benefits, and to safeguard natural and managed ecosystems, thus promoting innovative approaches to economic development that are socially and culturally appropriate, and environmentally sustainable.

The MAB programme provides a unique platform for cooperation on research and development, capacity-building and networking to share information, knowledge and experience on three interlinked issues: biodiversity loss, climate change and sustainable development. It contributes not only to better understanding of the environment, but also promotes greater involvement of science and scientists in policy development concerning the wise use of biological diversity.

As of December 2018, 686 biosphere reserves in 122 countries, including 20 transboundary sites, have been included in the World Network of Biosphere Reserves. Today, all MAB reserves form the World Network of Biosphere Reserves (WNBR) which serves three different functions:

1. **Conservation -** to contribute to the conservation of landscapes, ecosystems, species andgenetic variation;
2. **Development -** to foster economic and human development which is socially, culturallyand ecologically sustainable; and
3. **Logistic -** to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

Fundamentally, the network of MAB Reserves aims to be an international tool to develop and implement sustainable development and to contribute towards the Millennium Development Goals. Physically, each MAB reserve should contain three zones: one or more core zones which are legally protected; and clearly identified buffer and transition zones. The transition zone may be referred to as an area of co-operation.

**Supported by:**

The United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and the Biosphere (MAB) Programme.

**Year of creation:**

1971 (launch of MAB programme). The first MAB reserves were designated in 1976.

**Coverage**

Global network of 631 marine and terrestrial sites covering 119 countries, including 14transboundary sites (Year: 2014).

**Criteria:**

According to the 1995 Statutory Framework for the World Network of Biosphere Reserves,for an area to be qualified for designation as a MAB reserve it should:

1. Encompass a mosaic of ecological systems representative of major biogeographic regions,including a gradation of human interventions;
2. Be of significance for biological diversity conservation;
3. Provide an opportunity to explore and demonstrate approaches to sustainable developmenton a regional scale;
4. Have an appropriate size to serve the three functions of biosphere reserves;

5. Include appropriate zonation of core area(s),buffer zone(s) and an outer transition area;
6. Provide organisational arrangements for the involvement and participation of a suitable range of inter alia public authorities, local communities and private interests in the design and carrying out the functions of a biosphere reserve; and
7. Make provisions for a) mechanisms to manage human use and activities in the buffer zone(s), b) a management policy or plan for the area as a biosphere reserve, c) a designatedauthority or mechanism to implement this policy or plan, and d) programmes for research, monitoring, education or training.

**CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora):**

CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora, also known as the Washington Convention) is a multilateral treaty to protect endangered plants and animals. It was drafted as a result of a resolution adopted in 1963 at a meeting of members of the International Union for Conservation of Nature (IUCN). The convention was opened for signature in 1973 and CITES entered into force on 1 July 1975. Itsaim is to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species in the wild, and it accords varying degrees of protection to more than 35,000 species of animals and plants. In order to ensure that the General Agreement on Tariffs and Trade (GATT) was not violated, the Secretariat of GATT was consulted during the drafting process.
As of 2018, Secretary-General of the CITES Secretariat is Ivonne Higuero.

**CITES coverage & scope:**

• 179 member countries
• Regulates international trade of 35,000+ listed species (live, dead, parts and derivatives)

**Value of CITES trade**

- Record of 13 million trade transactions

Globally valued in billions of US Dollars

**Examples:**

– Queen conch: $ 60 MM/year

– Python skins = $ 1 BN/year

– Bigleaf mahogany = $ 33 MM/year

**CITES Appendix:**

**CITES Appendix I**

- Species threatened with extinction, which are or may be affected by trade
- International (commercial) trade in wild specimens is generally prohibited
- 3% of all listings (Conference of the Parties to decide)

**CITES Appendix II**

- Species not necessarily currently threatened with extinction, but may become so unless tradeis strictly regulated to avoid utilization incompatible with their survival
- Also, species that resemble species already included in Appendix II
- International (commercial) trade is permitted but regulated
- 96% of all listings (Conference of the Parties to decide)

**CITES Appendix III**

- Species for which a country is asking Parties to help with its protection
- International trade is permitted but regulated (less restrictive than Appendix II)
- 1% of CITES trade (no CoP decision needed)

## 6. Legal aspects of biodiversity and conservation: International Conventions; Important National legal instruments – Acts, Rules and Policies.

**Introduction:**

Several international conventions focus on biodiversity issues: the Convention on Biological Diversity (year of entry into force: 1993), the Convention on Conservation of Migratory Species, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1975), the International Treaty on Plant Genetic Resources for Food and Agriculture (2004), the Ramsar Convention on Wetlands (1971), the World Heritage Convention (1972) and the International Plant Protection Convention (1952), the International Whaling Commission (1946).

Biodiversity-related conventions work to implement actions at the national, regional and international level in order to reach shared goals of conservation and sustainable use. In meeting their objectives, the conventions have developed a number of complementary approaches (site, species, genetic resources and/or ecosystem-based) and operational tools (e.g., programmes of work, trade permits and certificates, multilateral system for access and benefit-sharing, regional agreements, site listings, funds).

The Convention on Biological Diversity (CBD), known informally as the Biodiversity Convention, is a multilateral treaty. The Convention has three main goals: the conservation of biological diversity (or biodiversity); the sustainable use of its components; and the fair and equitable sharing of benefits arising from genetic resources. Its objective is to develop national strategies for the conservation and sustainable use of biological diversity, and it is often seen as the key document regarding sustainable development.

The Convention was opened for signature at the Earth Summit in Rio de Janeiro on 5 June 1992 and entered into force on 29 December 1993. The United States is the only UN member state which has not ratified the Convention.[1] It has two supplementary agreements, the Cartagena Protocol and Nagoya Protocol.

The Cartagena Protocol on Biosafety to the Convention on Biological Diversity is an international treaty governing the movements of living modified organisms (LMOs) resulting from modern biotechnology from one country to another. It was adopted on 29 January 2000 as a supplementary agreement to the CBD and entered into force on 11 September 2003.

The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) to the Convention on Biological Diversity is another supplementary agreement to the CBD. It provides a transparent legal framework for the effective implementation of one of the three objectives of the CBD: the fair and equitable sharing of benefits arising out of the utilization of genetic resources. The Nagoya Protocol was adopted on 29 October 2010 in Nagoya, Japan, and entered into force on 12 October 2014.

2010 was also the International Year of Biodiversity, and the Secretariat of the CBD was its focal point. Following a recommendation of CBD signatories at Nagoya, the UN declared 2011 to 2020 as the United Nations Decade on Biodiversity in December 2010. The Convention's Strategic Plan for Biodiversity 2011-2020, created in 2010, include the Aichi Biodiversity Targets.

The meetings of the Parties to the Convention are known as Conferences of the Parties (COP), with the first one (COP 1) held in Nassau, Bahamas, in 1994 and the most recent one (COP 15) in 2021/2022 in Kunming, China and Montreal, Canada.[2]

In the area of marine and coastal biodiversity CBD's focus at present is to identify Ecologically or Biologically Significant Marine Areas (EBSAs) in specific ocean locations based on scientific criteria. The aim is to create an international legally binding instrument (ILBI) involving area-based planning and decision-making under UNCLOS to support the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction (BBNJ).

**Biodiversity-related conventions:**

**Convention on Biological Diversity**

The objectives of the CBD are the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from commercial and other utilization of genetic resources. The agreement covers all ecosystems, species, and genetic resources.

**Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)**

The Secretariat of the IPPC is hosted by the Food and Agriculture Organization of the United Nations (FAO).

**International Whaling Commission (IWC)**

The IWC was established in 1946 as the global body responsible for management of whaling and conservation of whales. Today the IWC has 88 member countries. The mandate has not changed but many new conservation concerns exist and the IWC work programme now also includes bycatch & entanglement, ship strikes, ocean noise, pollution and debris, and sustainable whale watching. The purpose of the IWC is to provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry.

**A guide to the contents of each convention's website is available here**

While each convention stands on its own—with its own specific objectives and commitments—inter-linkages between the issues each addresses, and potential complementarities in their monitoring and implementation processes, provide a basis for cooperation.

The governing bodies of each Convention have set out specific mandates for cooperation among the biodiversity-related conventions. In line with these mandates, reference to cooperation is made in a number of decisions from these governing bodies, and has led to the development of memoranda of cooperation and joint work programmes between the conventions.

These provisions have resulted in a wide range of cooperative activities being undertaken by the Conventions in support of shared goals.

To further enhance cooperation, a Biodiversity Liaison Group comprising the executive heads of the biodiversity-related conventions was established in 2002 and recently updated in 2014. Options for advancing cooperation have been put forward at the meetings of the Biodiversity Liaison Group and other meetings.

**Thematic Programmes and Cross-Cutting Issues:**

The Conference of the Parties (COP) has established seven thematic programmes of work (listed below) which correspond to some of the major biomes on the planet. Each programme establishes a vision for, and basic principles to guide future work.

They also set out key issues for consideration, identify potential outputs, and suggest a timetable and means for achieving these. Implementation of the work programmes depends on contributions from Parties, the Secretariat, relevant intergovernmental and other organizations. Periodically, the COP and the SBSTTA review the state of implementation of the work programmes.

- Agricultural Biodiversity
- Dry and Sub-humid Lands Biodiversity
- Forest Biodiversity
- Inland Waters Biodiversity
- Island Biodiversity
- Marine and Coastal Biodiversity
- Mountain Biodiversity

***Cross-Cutting Issues***

The COP has also initiated work on key matters of relevance to all thematic areas. These cross-cutting issues correspond to the issues addressed in the Convention's substantive provisions in Articles 6-20, and provide bridges and links between the thematic programmes. Some cross cutting initiatives directly support work under thematic programmes, for example, the work on indicators provides information on the status and trends of biodiversity for all biomes. Others develop discrete products quite separate from the thematic programmes. The work done for these cross-cutting issues has led to a number of principles, guidelines, and other tools to facilitate the implementation of the Convention and the achievement of the 2010 biodiversity target.

- Aichi Biodiversity Targets
- Access to Genetic Resources and Benefit-sharing
- Biological and Cultural Diversity
- Biodiversity for Development
- Capacity Building
- Climate Change and Biodiversity

- Communication, Education and Public Awareness
- Digital sequence information on genetic resources
- Economics, Trade and Incentive Measures
- Ecosystem Approach
- Ecosystem Restoration
- Gender and Biodiversity
- Global Strategy for Plant Conservation
- Global Taxonomy Initiative
- Health & Biodiversity
- Impact Assessment
- Identification, Monitoring, Indicators and Assessments
- Invasive Alien Species
- Liability and Redress - Art. 14(2)
- New & Emerging Issues
- Peace and Biodiversity Dialogue Initiative
- Protected Areas
- Sustainable Use of Biodiversity
- Sustainable Wildlife Management
- Technical and Scientific Cooperation
- Technology Transfer
- Tourism and Biodiversity
- Traditional Knowledge, Innovations and Practices - Article 8(j)

The CITES aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Through its three appendices, the Convention accords varying degrees of protection to more than 30,000 plant and animal species.

Please note that the International University of Andalusia offers a Master's Degree Course on CITES and CBD Implementation.

**Convention on the Conservation of Migratory Species of Wild Animals**

The CMS, or the Bonn Convention aims to conserve terrestrial, marine and avian migratory species throughout their range. Parties to the CMS work together to conserve migratory species and their habitats by providing strict protection for the most endangered migratory species, by concluding regional multilateral agreements for the conservation and management of specific species or categories of species, and by undertaking co-operative research and conservation activities.

**The International Treaty on Plant Genetic Resources for Food and Agriculture**

The objectives of the Treaty are the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security. The Treaty covers all plant genetic resources for food and agriculture, while its Multilateral System of Access and Benefit-sharing covers a specific list of 64 crops and forages. The Treaty also includes provisions on Farmers' Rights.

**Convention on Wetlands (popularly known as the Ramsar Convention)**

The Ramsar Convention provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The convention covers all aspects of wetland conservation and wise use, recognizing wetlands as ecosystems that are extremely important for biodiversity conservation in general and for the well-being of human communities.

**World Heritage Convention (WHC)**

The primary mission of the WHC is to identify and conserve the world's cultural and natural heritage, by drawing up a list of sites whose outstanding values should be preserved for all humanity and to ensure their protection through a closer co-operation among nations.

**International Plant Protection Convention (IPPC)**

The IPPC aims to protect world plant resources, including cultivated and wild plants by preventing the introduction and spread of plant pests and promoting the appropriate measures for their control. The convention provides the mechanisms to develop the International Standards for Phytosanitary Measures (ISPMs), and to help countries to implement the ISPMs and the other obligations under the IPPC, by facilitating the national capacity development, national reporting and dispute settlement.

***Major Groups***

For implementation of the Convention, the involvement of major stakeholders is imperative and therefore encouraged and supported by the Secretariat. The list below provides links to initiatives for a number of different groups:

- Business
- Local Authorities
- Parliamentarians
- Universities and the Scientific Community
- Children & Youth
- Non-Governmental Organizations (NGOs)

**Acts, Rules and Policies:**

**Biodiversity Act**

***Salient Provisions of Biological Diversity Act, 2002***

- Section - 3: All foreign national require approval from NBA for obtaining Biological Resources.
- Section - 4: Indian individuals/entities to seek approval before transferring knowledge / research and material to foreigners.
- Section - 5: Guidelines for Government sponsored collaborative research projects.
- Section - 6: Prior approval of NBA before applying for any kind of IPR based on research conducted on biological material and or associated knowledge obtained from India.
- Section - 7: Indians required providing prior intimation to State Biodiversity Boards for obtaining biological material for commercial purposes. SBB can regulate such access. Growers and cultivators of Biological Diversity and *vaids* and *hakims* who are practicing Indian system of medicines and local people exempted.
- Section - 8: Establishment of NBA, its composition.

- Section - 13: Committees of NBA
- Section - 18: Functions and powers of NBA
- Section - 19: Approval by the NBA
- Section - 21: Determination of equitable benefit sharing by NBA
- Section - 22: Establishment of State Bio-diversity Boards
- Section - 23: Function of the State Bio-diversity Boards
- Section - 24: Powers of State Bio-diversity Boards
- Section - 26 : National Biodiversity Fund
- Section - 32: State Bio-diversity Fund
- Section - 36: Central Government to develop National strategies, plans etc. for conservation of biodiversity.
- Section - 36: (1A): Central Government to issue direction to State Governments to take corrective measures for conservation of biodiversity
- Section - 36 (3)(i): Impact assessment of developmental projects on biodiversity
- Section - 36 (3)(ii): Regulate release of GMOs
- Section - 36 (4): Measures for protecting the traditional knowledge
- Section - 37: Biodiversity heritage sites
- Section - 38: Notifications of threatened species
- Section - 39: Designation of repositories
- Section-40: Exemption for normally traded commodities from purview of the act.
- Section - 41: Establishment of Biodiversity Management Committees by local bodies.
- Section - 42: Local Biodiversity Fund
- Section - 52 A: Appeals to High Court on the decision of NBA / SBB
- Section - 53 B: Orders of NBA / SBB at par with civil courts.
- Section - 55: Penalties - imprisonment upto 5 years and or a fine of 10 lakhs or to the extent of damage caused.
- Section - 59: Act to have effect in addition to other Acts
- Section - 61: Cognizance of offences
- Section - 62: Power of Central Government to make Rules

- Section - 63: Power of State Government to make Rules
- Section - 64: Power to make regulations
- Section - 65: Power to remove difficulties

***Short title, extent and commencement***

- This Act may be called the Biological Diversity Act, 2002.
- It extends to the whole of India.
- It shall come into force on such date as the Central Government may, by notification in the Official Gazette, appoint:

  Provided that different dates may be appointed for different provisions of this Act and any reference in any such provision to the commencement of this Act shall be construed as a reference to the coming into force of that provision.

***Definitions***

In this Act, unless the context otherwise requires,-

(a) "benefit claimers" means the conservers of biological resources, their byproducts, creators and holders of knowledge and information relating to the use of such biological resources, innovations and practices associated with such use and application;

(b) "biological diversity" means the variability among living organisms from all sources and the ecological complexes of which they are part, and includes diversity within species or between species and of eco systems;

(c) "biological resources" means plants, animals and micro organisms or parts thereof, their genetic material and by products (excluding value added products) with actual or potential use or value, but does not include human genetic material;

(d) "bio survey and bio utilization" means survey or collection of species, subspecies, genes, components and extracts of biological resource for any purpose and includes characterization, inventorisation and bioassay;

(e) "Chairperson" means the Chairperson of the National Biodiversity Authority or, as the case may be, of the State Biodiversity Board;

(f) "commercial utilization" means end uses of biological resources for commercial utilization such as drugs, industrial enzymes, food flavours, fragrance, cosmetics, emulsifiers, oleoresins, colours, extracts and genes used for improving crops and livestock through genetic intervention, but does not include conventional breeding or traditional practices in use in any agriculture, horticulture, poultry, dairy farming, animal husbandry or bee keeping;

(g) "fair and equitable benefit sharing" means sharing of benefits as determined by the National Biodiversity Authority under section 21;

(h) "local bodies" means Panchayats and Municipalities, by whatever name called, within the meaning of clause (1) of article 243B and clause (1) of article 243Q of the Constitution and in the absence of any Panchayats or Municipalities, institutions of self government constituted under any other provision of the Constitution or any Central Act or State Act;

(i) "member" means a member of the National Biodiversity Authority or a State Biodiversity Board and includes the Chairperson;

(j) "National Biodiversity Authority" means the National Biodiversity Authority established under section 8;

(k) "prescribed" means prescribed by rules made under this Act;

(l) "regulations" means regulations made under this Act;

(m) "research" means study or systematic investigation of any biological resource or technological application, that uses biological systems, living organisms or derivatives thereof to make or modify products or processes for any use;

(n) "State Biodiversity Board" means the State Biodiversity Board established under section 22;

(o) "sustainable use" means the use of components of biological diversity in such manner and at such rate that does not lead to the long term decline of the biological diversity thereby maintaining its potential to meet the needs and aspirations of present and future generations;

(p) "value added products" means products which may contain portions or extracts of plants and animals in unrecognizable and physically inseparable form.

***Functions and Powers of the National Biodiversity Authority***

1. It shall be the duty of the National Biodiversity Authority to regulate activities referred to in sections 3, 4 and 6 and by regulations issue guidelines for access to biological resources and for fair and equitable benefit sharing.
2. The National Biodiversity Authority may grant approval for undertaking any activity referred to in sections 3, 4 and 6.
3. The National Biodiversity Authority may-
4. (a) advise the Central Government on matters relating to the conservation of biodiversity, sustainable use of its components and equitable sharing of benefits arising out of the utilization of biological resources;

   (b) advise the State Governments in the selection of areas of biodiversity importance to be notified under sub section (1) of section 37 as heritage sites and measures for the management of such heritage sites;

   (c) perform such other functions as may be necessary to carry out the provisions of this Act.
5. The National Biodiversity Authority may, on behalf of the Central Government, take any measures necessary to oppose the grant of intellectual property rights in any country outside India on any biological resource obtained from India or knowledge associated with such biological resource which is derived from India.

**Other Legal Acts:**

1. Fisheries Act, 1897
2. Destructive Insects and Pests Act, 1914
3. The Indian Forest Act, 1927
4. Agricultural Produce (Grading and Marketing) Act, 1937
5. Indian Coffee Act, 1942
6. Import and Export (Control) Act, 1947
7. Rubber (Production and Marketing) Act, 1947
8. Tea Act, 1953
9. Mining and Mineral Development (Regulation) Act 1957

10. Prevention of Cruelty to Animal Act, 1960
11. Customs Act, 1962
12. Spices Board Act, 1986
13. Seeds Act, 1966
14. The Patents Act, 1970
15. Wildlife (Protection) Act, 1972
16. Water (Prevention and Control of Pollution) Act, 1974
17. Tobacco Board Act, 1975
18. Territorial Water, Continental Shelf, Exclusive Economic Zone and other Maritime Zones Act, 1976
19. Water (Prevention and Control of Pollution) Cess Act, 1977
20. Forest (Conservation) Act, 1980
21. Air (Prevention and control of Pollution) Act 1981
22. Agricultural and Processed Food Products Export Development Authority Act 1985/1986
23. Environment (Protection) Act, 1986
24. National Diary Development Board Act, 1987
25. Foreign Trade (Development and Regulation) Act, 1992
26. Protection of Plant varieties and Farmer's Rights (PPVFR) Act, 2001
27. Biological Diversity Act, 2002
28. The Food Safety and Standards Act, 2006
29. Scheduled Tribes and other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006
30. National Green Tribunal Act 2010

**Environment Protection Act, 1986**

As compared to all other previous laws on environment protection, the Environment (Protection) Act, 1986 is a more effective and bold measure to fight the problem of pollution.

The genesis of the Environmental (Protection) Act, 1986, is in Article 48A (Directive Principles of State Policy) and Article 51A (g) (Fundamental Duties) of the Indian Constitution.

The Act empowers the Central Government to take all appropriate measures to prevent and control pollution and to establish effective mechanisms to protect and improve the quality of the environment and protecting controlling and abating environmental pollution.

The Central Government or any other person duly authorized is empowered to collect the samples of air, water, soil, or other substances as evidence of the offenses under the Environment (Protection) Act, 1986.

The Act prescribes a special procedure for handling hazardous substances and the concerned person has to handle the hazardous substances according to the procedure of the Act.

The Environment (Protection) Act, 1986 has relaxed the rule of "Locus Standi" and because of such relaxation, even a common citizen can approach the Court provided he has given a notice of sixty days of the alleged offense and his intention to make a complaint to the Central Government or any other competent authority.

This Act also empowers and authorizes the Central Government to issue directions for the operation or process, prohibition, closure, or regulation of any industry. The Central Government is also authorized to stop, regulate the supply of electricity or water or any other service directly without obtaining the order of the Court in this regard.

The Act consists of and deals with more stringent penal provisions. The minimum penalty for contravention or violation of any provision of the law is imprisonment for a term which may extend to five years or fine up to one lakh rupees, or both. The Act also provides for the further penalty if the failure or contravention continues after the date of conviction. If the failure or contravention continues beyond the period of one year, then the offender is punished with imprisonment for a term which may extend to seven years.

It grants immunity to the officers of the Government for any act done under the provisions of this Act or the powers vested in them or functions assigned to them under this Act.

The Act debars the Civil Courts from having any jurisdiction to entertain any suit or proceeding in respect of an action, direction, order issued by the Central Government, or other statutory authority under this Act.

Under the Act, there will be the supremacy of provision. In other words, the provisions of this Act and the rules or orders made under this Act shall have effect and supremacy over anything inconsistent contained in any enactment other than this Act.

**Biological Diversity Act, 2002**

The Biological Diversity Act 2002 was born out of India's attempt to realize the objectives enshrined in the United Nations Convention on Biological Diversity (CBD) 1992 which recognizes the sovereign rights of states to use their Biological Resources.

Objectives "Conservation of biological diversity;" Sustainable use of its components; and " Fair and equitable sharing of the benefits arising from the utilization of genetic resources.

The Act envisages a three-tier structure to regulate access to the biological resources, comprising of National Biodiversity Authority (NBA), State Biodiversity Boards (SBB), and Biodiversity Management Committees (BMC) at the local level.

**Indian Forest Act, 1927**

1865: The Indian Forests Act of 1865 extended the British Colonial claims over forests in India

1878: The Forest Act of 1878 was introduced and it truncated the centuries-old traditional use by communities of their forests and secured the colonial government's control over the forestry. The provision of this Act established a virtual State monopoly over the forests in a legal sense on one hand and attempted to establish, on the other, that the customary use of the forests by the villagers was not a 'right', but a 'privilege' that could be withdrawn at will.

Indian Forest Act, 1927: The main objective was to secure exclusive state control over forests to meet the demand for timber. Most of these untitled lands had traditionally belonged to the forestdwelling communities. The Act defined state ownership regulated its use and appropriated the power to substitute or extinguish customary rights. The Act facilitates three categories of forests, namely y Reserved forests y Village forests y Protected forests Reserved forests are the most protected within these categories. No rights can be acquired in reserved forests except by succession or under a grant or contract with the government. Felling trees, grazing cattle, removing forest products, quarrying, fishing, and hunting are punisha with a fine or imprisonment. Although the Indian Forest Act is a federal act, many states have enacted similar forest acts but with some modifications.

**Forest Conservation Act, 1980**

It was passed to check further deforestation and conserve forests. Major objectives of this act were: " Restricting the use of forest land for non-forest purposes " Preventing the de-reservation of forests that have been reserved under the Indian Forest Act, 1927 " Restrict leasing of forest land to private individuals, authority, corporations not owned by the Government " To prevent clear-felling of naturally grown trees

In essence, the Act merely shifts powers for decisions concerning forest land use from the State to the Centre.

**National Forest Policy, 1988**

The principal aim of National Forest Policy, 1988 is to ensure environmental stability and maintenance of ecological balance including atmospheric equilibrium which is vital for sustenance of all life forms, human, animal, and plant.

**Objectives** "Conserving the natural heritage of the country by preserving the remaining natural forests with the vast variety of flora and fauna, which represent the remarkable biological diversity and genetic resources of the country."

Checking soil erosion and denudation in the catchments areas of rivers, lakes, reservoirs in the interest of soil and water conservation, for mitigating floods and droughts, and for the retardation of siltation of reservoirs. " Checking the extension of sand-dunes in the desert areas of Rajasthan and along the coastal tracts. " Increasing substantially the forest/tree cover in the country through massive afforestation and social forestry programmes, especially on all denuded, degraded and unproductive lands. " Increasing the productivity of forests to meet essential national needs. " Encouraging efficient utilization of forest produce and maximizing substitution of wood. Note: Recently, the Forest Policy, 2016 was repealed. The MoEF & CC has framed a new draft National Forest Policy 2018 which proposes climate change mitigation through sustainable forest management.

**New Draft National Forest Policy, 2018**

It aims to bring a minimum of one-third of India's total geographical area under forest cover through scientific interventions and enforcing strict rules to protect the dense cover.

Unlike the previous policies, which stressed on environmental stability and maintenance of ecological balance, the 2018 policy focuses on the international challenge of climate change.

While the ministry has done away with the environment cess that was proposed in the scrapped 2016 draft policy, it has retained several controversial clauses in its 2018 draft.

Public-private participation models: PPP models would be developed for undertaking afforestation and reforestation activities in degraded forest areas and forest areas available with Forest Development Corporations and outside forests.

The ecologically sensitive catchment areas shall be stabilized with suitable soil and water conservation measures, and also by planting suitable trees and grass-like bamboo," the draft suggests. It also suggests setting up of two national level bodies—National Community Forest Management (CFM) Mission and National Board of Forestry (NBF)—for better management of the country's forests.

As per the draft NBF needs to be headed by the central minister in charge of forests. The draft calls for state boards of forestry headed by state ministers in charge of forests to be established for ensuring inter-sectoral convergence, simplification of procedures, conflict resolution, among other things.

Checking man-animal conflict: Quick response, dedicated teams of well equipped and trained personnel, mobility, strong interface with health and veterinary services, rescue centers, objective and speedy assessment of damage, and quick payment of relief to the victims would be at the core of the short-term action.

According to the new draft, efforts will be made to achieve harmonization between policies and laws like the Forest Rights Act (FRA) 2006.

Participatory forest management: There is a need to further strengthen this participatory approach, for which a National Community Forest Management (CFM) Mission will be launched.

Finances required for management of forests: The compensatory afforestation fund which is being transferred to the states would be a major source of funds for taking up afforestation and rehabilitation works in degraded forest areas as well as for bringing new areas under forest and tree cover.

Efforts for tapping funds from other national sectors like rural development, tribal affairs, national highways, railways, coal, mines, power, etc., will be taken for appropriate implementation of linking greening with infrastructure and other development activities.

It also calls for "promotion of trees outside forests and urban greens", while stating that it will be taken up in "mission mode".

**The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006**

Forest Rights Act, 2006 provides for the restitution of deprived forest rights across India, including both individual rights to cultivated land in forestland and community rights over common property resources.

The Act is significant as it provides scope and historic opportunity of integrating conservation and livelihood rights of the people.

FRA is a potential tool "To empower and strengthen the local self-governance " To address the livelihood security of the people " To address the issues of Conservation and management of the Natural Resources and conservation governance of India.

For the first time the Forest Rights Act recognizes and secures: " Community Rights in addition to their rights " Right to protect, regenerate or conserve or manage any community forest resource which the communities have been traditionally protecting and conserving for sustainable use. " Right to intellectual property and traditional knowledge related to biodiversity and cultural diversity " Rights of displaced communities & Rights over developmental activities

**Nodal Agency for the implementation is MoTA.**

This Act is applicable for Tribal and Other Traditional Forest Dwelling Communities. It stands for "Ministry of Tribal Affairs."

The Act provides for recognition of forest rights of other traditional forest dwellers provided they have for at least three generations before 13.12.2005 primarily resided in and have depended on the forest or forest land for bonafide livelihood needs. A "generation" for this purpose would mean a period comprising of 25 years.

The maximum limit of the recognizing rights on forest land is 4 ha.

National Parks and Sanctuaries have been included along with Reserve Forest, Protected Forests for the recognition of Rights.

The Act recognizes the right of ownership access to collect, use, and dispose of minor forest produce which has been traditionally collected within or outside village boundaries.

The Act has defined the term "minor forest produce" to include all non-timber forest produce of plant origin, including bamboo, brushwood, stumps, cane, tussar, cocoons, honey, wax, lac, tendu or kendu leaves, medicinal plants and herbs, roots, tubers and the like.

The Act provides for the forest right relating to the Government providing for diversion of forest land for schools, hospitals, anganwadis, drinking water supply, and water pipelines, roads, electric and telecommunication lines, etc.

The rights conferred under the Act shall be heritable but not alienable or transferable and shall be registered jointly in the name of both the spouses in the case of married persons and the name of the single head, in the case of a household headed by a single person and in the absence of a direct heir, the heritable right shall pass on to the next of kin

The Act provides that no member of a forest-dwelling Scheduled Tribe or other traditional forest dwellers shall be evicted or removed from forest land under his occupation till the recognition and verification procedure is completed.

As per the Act, the Gram Sabha has been designated as the competent authority for initiating the process of determining the nature and extent of individual or community forest rights or both that may be given to the forest-dwelling Scheduled Tribes and other traditional forest dwellers.

## 7. Let's sum up

- Ecology: branch of science that deals with interaction between living organisms with each other and their surroundings. Ecological systems are studied at several different levels from individuals and populations to ecosystems and biosphere level.
- Within the discipline of ecology, researchers work at four specific levels, sometimes discretely and sometimes with overlap: organism, population, community, and ecosystem.
- There are many practical applications of ecology in conservation biology, wetland management, natural resource, city planning, community health, economics, basic and applied science, and human social interaction.
- Descriptive describes organisms and their interactions within ecosystems. This is the foundation of all ecological science. Functional studies proximate causes, the dynamic responses of populations and communities to immediate factors of environment. Evolutionary considers organisms and the relationships between organisms as historical products of evolution.
- A hypothesis can be defined as a tentative explanation of the research problem, a possible outcome of the research, or an educated guess about the research

outcome.

- Probabilistic Ecological Models deal with the statistical probability of occurrence of certain phenomenon. Probabilistic Models are based on the exact knowledge of the most desirable information.
- Statistical approaches provide the means of understanding a process with some specified level of uncertainty. In statistics, an unknown true characteristic of a system is called a parameter.
- Remote sensing as a tool opened up new vistas of perception of things that exist toofar or on extensive spatial scales. Nowadays there is a big assortment of satellite systems actively recording information about the Earth.
- Climate diagrams are brief summaries of average climatic variables and their time course. They have proven useful for a wide range of sciences, industry, teaching & areuseful for planning and design.
- Abiotic factors are the non-living parts of an environment. These include things such as sunlight, temperature, wind, water, soil and naturally occurring events such as storms, fires and volcanic eruptions. Biotic factors are the living parts of an environment, such as plants, animals and micro-organisms.
- Habitat is a set of the place of environmental conditions in which particular organism lives and adapt the situation accordingly. A niche is nothing but an idea or role played by organisms that how they can live in an environment including their diet, shelter, etc. Mainly niche is concerned with the factor of gaining energy by organisms and supplying it to other, in the ecosystem.
- Population ecology is a sub-field of ecology that deals with the dynamics of species populations and how these populations interact with the environment. It is the study ofhow the population sizes of species change over time and space. Some of the most important characteristics of population are population density, natality, mortality, population growth and age distribution of population.
- A plant community is a collection or association of plant species within a designated geographical unit, which forms a relatively uniform patch, distinguishable from neighboring patches of different vegetation types. The

components of each plant community are influenced by soil type, topography, climate and human disturbance.

- Each biotic community consists of very diverse organisms belonging to different kingdoms of living things. The number of species and abundance of population in communities also vary greatly. The organisms in a community depend upon each other as well as upon the non-living environment for food, shelter and reproduction.
- A diversity index (also called phylogenetic indices or phylogenetic metrics) is a quantitative measure that reflects how many different types (such as species) there are in a dataset (a community) and that can simultaneously take into account the phylogenetic relations among the individuals distributed among those types, such as richness, divergence or evenness.
- Ecological succession is the process of change in the species structure of an ecological community over time. The time scale can be decades, or even millions of years after a mass extinction. The community begins with relatively few pioneering plants and animals and develops through increasing complexity until it becomes stable or self- perpetuating as a climax community.
- Ecosystem may be defined as the system resulting from the integration of all living and non-living factors of the environment. An ecosystem has two major components; biotic and abiotic
- The bulk of any ecosystem is plants compared to which only a small fraction is animal life. Therefore, measurement of energy of an ecosystem primarily involves plants.And because plants represent the first or primary trophic level, plant production is measured as Gross Primary Production, which is equivalent to the energy fixed during photosynthesis.
- A food chain may be defined as the transfer of energy and nutrients from the source in plants through a series of organisms with repeated processes of eating and being eaten. Food chains are not always simple and isolated but are interconnected with one another. The interlocking pattern of food chains or a matrix of food chains, with all sorts of short circuits and connections is often

called the food web or food net.

- Ecological pyramids are the graphic representations of trophic levels in an ecosystem. They are pyramidal in shape and they are of three types.
- Scientists divide ecosystems into terrestrial and non-terrestrial. Ecosystems may be further classified by their geographical region and dominant plant type six primary terrestrial ecosystems exist: Tundra, Taiga, Temperate deciduous forest, Tropical rain forest, Grassland; and Desert.
- Freshwater ecosystems are a subset of Earth's aquatic ecosystems. They include lakes and ponds, rivers, streams, springs, bogs, and wetlands. They can be contrasted with marine ecosystems, which have a larger salt content. Freshwater habitats can be classified by different factors, including temperature, light penetration, nutrients, and vegetation.
- Biogeography is the study of the distribution of species and ecosystems in geographic spaceand through geological time. Organisms and biological communities often vary in a regular fashion along geographic gradients of latitude, elevation, isolation and habitat area.
- Biodiversity is defined as the intrinsically-inbuilt plus the externally-imposed variability in and among living organisms existing in terrestrial, marine and other ecosystem at a specific period of time.
- The term megadiverse country refers to any one of a group of nations that harbour the majority of Earth's species and high numbers of endemic species. Conservation International identified 17 megadiverse countries in 1998. A biodiversity hotspot is a biogeographic region with a significant reservoir of biodiversity that is under threat from humans.
- Biodiversity is considered as a reservoir of resources to be used for the manufacture of food, medicine, industrial products, etc. But with an increased demand of rapid population growth, biodiversity is gradually depleting.
- The IUCN Red list of threatened species is also known as the IUCN Red list or Red data list. Species are classified by the IUCN Red list into nine groups, set through criteria such as rate of decline, population size, area of geographic distribution,

and degree of population and distribution fragmentation.

- Conservation of biodiversity is protection, upliftment and scientific management of biodiversity so as to maintain it at its threshold level and derive sustainable benefits for the present and future generation. Conservation can broadly be divided into two types in-situ conservation and ex-situ conservation.
- Botanical gardens and zoos are the most conventional methods of ex-situ conservation, all of which house whole, protected specimens for breeding and reintroduction into the wild when necessary and possible. These facilities provide not only housing and care for specimens of endangered species, but also have an educational value.
- WWF is an international non-governmental organization founded in 1961, working in the field of the wilderness preservation, and the reduction of human impact on the environment. It was formerly named the World Wildlife Fund, which remains its official name in Canada and the United States.
- MAB is an intergovernmental scientific programme, launched in 1971 by UNESCO, which aims to establish a scientific basis for the improvement of relationships betweenpeople and their environments.
- CITES is a multilateral treaty to protect endangered plants and animals. It was drafted as a result of a resolution adopted in 1963 at a meeting of members of the IUCN.

## 8. Suggested Readings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3. Shukla, R.S. & Chandel, P.S. Plant Ecology, Latest Ed., S. Chandel and Co.

4. Singh, J.S., Singh, S.P., Gupta, S. (2006). Ecology Environment and Resource Conservation. Anamaya Publications, New Delhi, India.
5. Wilkinson, D.M. (2007). Fundamental Processes in Ecology: An Earth Systems Approach.Oxford University Press. U.S.A.
6. Kormondy, E.J. (1996). Concepts of ecology. PHI Learning Pvt. Ltd., Delhi, India. 4thedition.
7. Chapman, J. L. & Reiss, M. J. 1999. Ecology Principles and Applications. CambridgeUniversity Press, U.K.
8. Krishnamurthy, K.V. An Advanced Text Book on Biodiversity, 2003, Oxford & IBHPublishing Co. Ltd. Coyle.
9. http://www.biologydiscussion.com/
10. https://en.wikipedia.org/

## 9. Assignments

1. What is ecotone?
2. Who coined the term ecology?
3. Write about biotic factor of ecosystem.
4. Define character displacement.
5. Write the difference between Niche Width and Overlap?
6. Define deforestation.
7. What is net primary productivity?
8. Write a short note on remote sensing.
9. What is meant by climate diagram?
10. How fundamental niche and realized niche can be differentiated to each other?
11. Give examples of inverted pyramids.

12. Write short notes on any two:
    (a) Ecological pyramid
    (b) Food web
13. Name a few biotic and abitoic components of an ecosystem.
14. Explain the analytic characters of community.
15. What is key stone species?
16. What are the different zone of Biosphere reserves? Mention its role in ex-situconservation.
17. Give an account of general process of succession in nature.
18. What are the different types of speciation
19. Distinguish between allopatric and sympatric speciation.
20. What is guilds?
21. What is meant by carrying capacity?
22. Explain different characteristics of population ecology.
23. Differentiate between r and k-selection.
24. Give an account on survivorship curves.
25. What is physiognomy?
26. Describe the normal biological spectrum of Raunkiaer based on the position of buds.
27. What is succession? Describe the causes, trends and basic types of succession.
28. Give an account of general process of succession in nature.
29. Differentiate between autogenic and allogenic succession.
30. What is species diversity?
31. Write a short note on 'hot spots in India'.
32. Describe values and threats of biodiversity.
33. India has a rich biodiversity status. Explain?
34. What are the strategies of ex-situ conservation?
35. What are the appendices of CITES?
36. Explain different categories of IUCN with suitable diagram
37. When did oldest and recent mass extinction events occur in geological

history?

38. What is meant by cryopreservation?
39. Explain different strategies of in-situ conservation with example.
40. Discuss about major biogeographical region of India.

**All the materials are self writing and collected from ebook, journals and websites.**