Lecture 1
Evolution

1.Definition and historical review:

- **Introduction**

Evolution is the process of change in all forms of life over generations, and evolutionary biology is the study of how evolution occurs. Biological populations evolve through genetic changes that correspond to changes in the organisms' observable traits.

Genetic changes include mutations, which are caused by damage or replication errors in organisms' DNA. As the genetic variation of a population drifts randomly over generations, natural selection gradually leads traits to become more or less common based on the relative reproductive success of organisms with those traits.

All individuals have hereditary material in the form of genes received from their parents, which they pass on to any offspring. Among offspring there are variations of genes due to the introduction of new genes via random changes called mutations or via reshuffling of existing genes during sexual reproduction. The offspring differs from the parent in minor random ways. If those differences are helpful, the offspring is more likely to survive and reproduce. This means that more offspring in the next generation will have that helpful difference and individuals will not have equal chances of reproductive success. In this way, traits that result in organisms being better adapted to their living conditions become more common in descendant populations. These differences accumulate resulting in changes within the population. This process is responsible for the many diverse life forms in the world.

2. Origin of life:

Study of living organisms such as plants, animals and human etc. is the active area of life science. Now question is how you will define “LIFE”. Life is defined as “the ability of an organism to reproduce, grow, and produce energy through chemical reactions to utilize the outside materials”. But scientists and philosophers have tried to understand two important questions related to life:

1. How life originated on earth?
2. How different kinds of organisms are formed in the world?

So first the question is how earth formed and how its internal structure supports the life? Evidences suggest that earth and other planets in solar system came to existence around 4.5-5 billion years ago. Earth originally had two components: solid mass lithosphere and the surrounding gaseous envelope atmosphere. Once the temperature of primitive earth cooled down below 1000C, liquid components known as hydrosphere.

Evolution does not attempt to explain the origin of life (covered instead by abiogenesis), but it does explain how early life forms evolved into the complex ecosystem that we see today. Based on the similarities between all present-day organisms, all life on Earth is assumed to have originated through common descent from a last universal ancestor from which all known species have diverged through the process of evolution. NOW

Coming to our first question? How life originated on the earth?

Six major theories are proposed to explain the origin of life on earth. These theories are as follows:

1. **Theory of Special Creations:**

The theory of special creation is proposed that life on earth is created by a supernatural power, the **GOD**. According to the Christian and Muslim belief, god has created the universe, planet, animal, plant and human in six natural days. Similar beliefs are also been proposed by other religion as well. There are believes in the theory of special creation. These points are as follows:

1. All living organisms were created same day.
2. They were created in the present form.
3. Their bodies and organs are fully developed to meet the requirement to run the life.

Objective to the theory of special creation:

1. It was purely based on religious belief.
2. There were no experimental evidences to support the assumptions.
3. The age of different fossils proves that living organism appear on earth in different time frame.

4. **Theory of spontaneous generations:**

The theory of spontaneous generation or abiogenesis assumes that non-living material in a spontaneous manner give rise to life. There are several observations supporting this theory, which are as follows:

1. Hair of horse tail dipped in the water gives rise to horsehair worm, gordius.
2. Fly larvae develops on rotten meat.
3. In ancient Egypt, it was believe that frog, snake, crocodiles in the mud of Nile river warmed with sun.
4. Van Helmont claimed that he can produce mice from the dirty shirt and hadful of wheat grains kept in dark cupboard in 3 weeks.

Evidences against the theory of spontaneous generation:

Theory of spontaneous generation was criticized by Lazzaro Spallanzani, Francisco Redi and Louis Pasteur. These great scientists performed well designed scientific experiments to disprove the theory of spontaneous generations.

5. Theory of cosmozoic:

This theory was put forward by Richter and strongly supported by Arrhenius. The theory assumes that life was present in the form of resistant spores and appeared on earth from other planet. Since the condition of earth was supporting the life, these spores grew and evolved into different organisms. This theory was also known as "theory of panspermia or spore theory". The theory initially got the support from the fact that fossils of microorganism were found in meteorites in 1961. But no mechanism is known about the transfer of spores from other planet or whether these spores could survive the journey in space. The absence of life forms on any planet except earth and no details about the spores, its origin and mechanism of crossing interplanetary space and reaching earth. In addition, this theory doesn't add much into the fundamental details about origin of life. No scientific experiments were given to support the theory. As a result, the hypothesis didn't receive much attention.

6. Oparin and Haldane theory

The modern theory is also known as "chemical theory" or theory of primary abiogenesis. In the modern theory, the hypothesis of abiogenesis was proposed with a condition that the non-living materials can give rise to life in the condition of primitive earth. The condition of the primitive earth is different from the present conditions which donot permit abiogenesis. The idea of chemical theory was put forward by two scientists, A.I. Oparin and J.B.S Haldane. It has made following assumptions:

1. Spontaneous generation of life under the present environment is not possible.
2. Earth's atmosphere ~1 billion years is very different from the current conditions.
3. Primitive earth's atmosphere was reducing in nature.
4. Under these conditions, the chemical molecules (inorganic molecules) react with each other through a series of reactions to form organic substances and other complex biomolecules.
5. The solar energy and UV radiation provided the energy for the chemical reactions.

3. History of evolutionary thought

Explanations that have a physical basis began with the Greeks:

Thales (640 Thales (640-546 B.C.) the first natural explanation All life the first natural explanation. All life came from water.

Xenophanes (576-480 B.C.) and **Herodotus** (484-425 BC) recognized fossils as the remains of living creatures, and based on the distribution of fossil marine life speculated that oceans had formerly covered some of the land. The first recognition of environmental change through time and change in living creatures accompanying it.

Democritus (500-404 B.C.) distinguished between organic and inorganic systems. Organic systems were derived from inorganic systems through the natural properties of inorganic systems.

Empedocles (495-435 B.C.) gave a detailed explanation of the natural origin of life. There were 4 basic inorganic materials: fire, air, earth, and water and two basic forces. Love and hate. A proper mixture of materials forces and body parts created A proper mixture of materials, forces and body parts created a functional living organism. An improper mixture resulted in reduced survival. The first example of a hypothesis of differential survival in nature.

Hippocrates (460-370 B.C.) stressed an empirical approach. He stated two principles that seemed to be valid:

1. The inheritance of acquired characters habits or characteristics of the parent will be passed to the offspring
2. Principle of use and disuse a part that is used will become more elaborate and a part that is not used will be lost Variation was due to differences in environments and habits

Aristotle (384-322 B.C.) The first great naturalist:

1. He was the first to use the gradations in form among organisms to arrange them into a ladder like scale - with man at the top of the living world a teleological system.
2. Rejected metaphysical speculation but accepted the idea that species have fixed properties.
3. Returned to empiricism - studying by observing. Attempted to find general principles that agreed with observable facts.
4. Developed the beginnings of biology: anatomy, reproductive biology and ecology of many plants and animals.

Carolus Linnaeus (1707-1778) - Systema Naturae (1735) - a classification of plants and animals - a hierarchical classification with species organized into genera, and into families, orders, etc. He did not believe in change or common descent. He saw all species as fixed entities. 13 Linnaeus's purpose was to discover the pattern in God's creation.

Jean Baptiste LaMarck (1744-1829) he was interested in the apparent close fit between organisms and their environment, their adaptations. Questioned the idea that species were fixed, he suggested species could change in response to their environment. LaMarck's model did not allow for extinction of forms. Published his ideas in Philosophie Zoologique (1809).

Charles Darwin (1809–1882): was an English naturalist, geologist and biologist, best known for his contributions to the science of evolution.

Darwinism is a theory of biological evolution developed by Darwin and others, stating that all species of organisms arise and develop through the natural selection of small, inherited variations that increase the individual's ability to compete, survive, and reproduce. Also called Darwinian Theory, Darwin published On the Origin of Species in 1859.

Evidences against the theory of natural selection:

1. Perpetuation of Vestigial Organs: Vestigial organs are selected despite the fact that they are not useful for animals but even then they are preserved generation over generation.
2. No explanation for variation: Darwin could not be able to explain the source and mechanism of generation of variation in organisms.
3. Distinction between continuous and discontinuous variations: According to theory, Darwin assumed that any variation essential for animal survival will be carried forward to next generation. We know that it is not true as per present knowledge of genetics.
4. Disapproval of Pangenesis theory of Darwin: Darwin put forward the theory of Pangenesis to explain the process of inheritance. It was disapproved by the experiments performed by August Weismann in 1892.

Neo-Darwinism

5. Neo-Darwin is a modification of the original theory of Darwin to remove its short comings
6. Instead of continuous variations, mutations are believed to help form new species.
7. Variations accumulate in the gene pool and not in the individuals.
8. Neo-Darwinism incorporates isolation as an essential component of evolution. The theory can explain the occurrence of unchanged forms over millions of years.
9. Normally only those modifications are transferred to next generation which influence germ cells or where somatic cells give rise to germ cells.

Modern Synthetic Theory of Evolution

Further synthesis of Neo-Darwinism. Coupled with the knowledge of evolution at the molecular level (DNA, RNA, Genes, Genome etc.)

This theory of evolution is the result of the work of a number of scientists namely T. Dobzhansky, R.A. Fisher, J.B.S. Haldane, Swall Wright, Ernst Mayr, and G.L. Stebbins. Stebbins in his book, Process of Organic Evolution, discussed the synthetic theory.

It includes the following factors:

1. Natural selection
2. Gene mutations
3. Variation (Recombination)
4. Heredity
5. Isolation and speciation.

In addition, three accessory factors affect the working of these five basic factors:

1. Migration of individuals from one population to another.
2. Hybridization between races or closely related species.
3. Increase the amount of genetic variability available to a population. Influence the effects of chance acting on small populations.
4. May alter the way in which natural selection guides the course of evolution.

4.Mechanisms of Evolution

In nature difference between individuals in one species and between different species may be caused by fundamental forces of evolution:

1. **Natural Selection**
2. **Mutations**
3. **Gene Flow (migration)**
4. **Recombination or Variation**
5. **Genetic Drift**
6. **Isolation (speciation).**

1. Natural selection:

It brings about evolutionary change by favoring differential reproduction of genes which produces change in gene frequency from one generation to the next. Natural selection does not produce genetic change, but once it has occurred it acts to encourage some genes over others. Further, natural selection creates new adaptive relations between population and environment by favoring some gene combinations, rejecting others and constantly modifying and modeling the gene pool.

- **Types of natural selection**

Natural selection can take many forms. To make talking about this easier, we will consider the distribution of traits across a population in graphical form. In we see the normal bell curve of trait distribution. For example, if we were talking about height as a trait, we would see that without any selection pressure on this trait, the heights of individuals in a population would vary, with most individuals being of an average height and fewer being extremely short or extremely tall. However, when selection pressures act on a trait, this distribution can be altered.

I. Stabilizing selection

The most common of the types of natural selection is stabilizing selection, the population experiences stabilizing selection when selective pressures; select against the two extremes of a trait. Therefore, the median phenotype is the one selected for during natural selection. This does not skew the bell curve in any way. Instead, it makes the peak of the bell curve even higher than what would be considered normal.

Stabilizing selection is the type of natural selection that human skin color follows. Most humans are not extremely light skinned or extremely dark skinned. The majority of the species fall somewhere in the middle of those two extremes. This creates a very large peak right in the middle of the bell curve. This is usually caused by a blending of traits through incomplete or codominance of the alleles.

II. Directional selection

It derives its name from the shape of the approximate bell curve that is produced when all individuals' traits are plotted. Instead of the bell curve falling directly in the middle of the axes on which they are plotted, it skews either to the left or the right by varying degrees. Hence, it has moved one direction or the other.

Directional selection curves are most often seen when one coloring is favored over another for a species. This could be to help them blend into an environment; camouflage themselves from predators, or to mimic another species to trick predators. Other factors that may contribute to one extreme being selected for over the other include the amount and type of food available.

III. Disruptive Selection

In disruptive selection, selection pressures act against individuals in the middle of the trait distribution. It is also named for the way the bell curve skews when individuals are plotted on a graph. To disrupt means to break apart and that is what happens to the bell curve of disruptive selection. Instead of the bell curve having one peak in the middle, disruptive selection's graph has two peaks with a valley in the middle of them.

The shape comes from the fact that both extremes are selected for during disruptive selection. The median is not the favorable trait in this case. Instead, it is desirable to have one extreme or the other, with no preference over which extreme is better for survival. This is the rarest of the types of natural selection.

IV. Sexual Selection

Sexual Selection is another type of Natural Selection. However, it tends to skew the phenotype ratios in the population so they do not necessarily match what Gregor Mendel would predict for any given population. In sexual selection, the female of the species tends to choose mates based on traits they show that are more attractive. The fitness of the males is judged based on their attractiveness and those who are found more attractive will reproduce more and more of the offspring will also have those traits.

For example, consider a male peacock. Their giant, brightly colored tails make avoiding predators difficult, so what's the advantage of having such tails? Well, females choose male peacocks with brightly colored tails, so even though it's risky to be parading around predators with a bright tail, your chances of mating (and reproducing) are increased and thus this trait gets passed down (Figure5). The peacock is an example of sexual selection between the two sexes, or intersexual selection. Just like a muscular, bearded human, it's assumed that female peacocks choose brightly colored male peacocks because in order to produce such a large, colorful tail the male peacock must have good genes. These good genes, in turn, will contribute to the success of the offspring.

V. Artificial selection or Selective Breeding

Artificial selection is not a type of natural selection, obviously, but it did help Charles Darwin obtain data for his theory of natural selection. Artificial selection mimics natural selection in those certain traits is chosen to be passed down to the next generation. However, instead of nature or the environment in which the species lives being the deciding factor for which traits are favorable and which are not, it is humans that do the selecting of traits during artificial selection.

Perhaps the best-known use of artificial selection is dog breeding from wild wolves to dog show winners of the American Kennel Club (AKC), which recognizes over 700 different breeds of dogs.

Most of the breeds the AKC recognizes are the result of an artificial selection method known as crossbreeding wherein a male dog from one breed mates with a female dog of another breed to create a hybrid. One such example of a newer breed is the labradoodle, a combination of a Labrador retriever and a poodle.

Dogs, as a species, also offer an example of artificial selection in action. Ancient humans were mostly nomads who roamed from place to place, but they found that if they shared their food scraps with wild wolves, the wolves would protect them from other hungry animals. The wolves with the most domestication were bred and, over several generations, humans domesticated the wolves and kept breeding those that showed the most promise for hunting, protection, and affection. The domesticated wolves had undergone artificial selection and became a new species that humans called dogs (**Figure 6**).

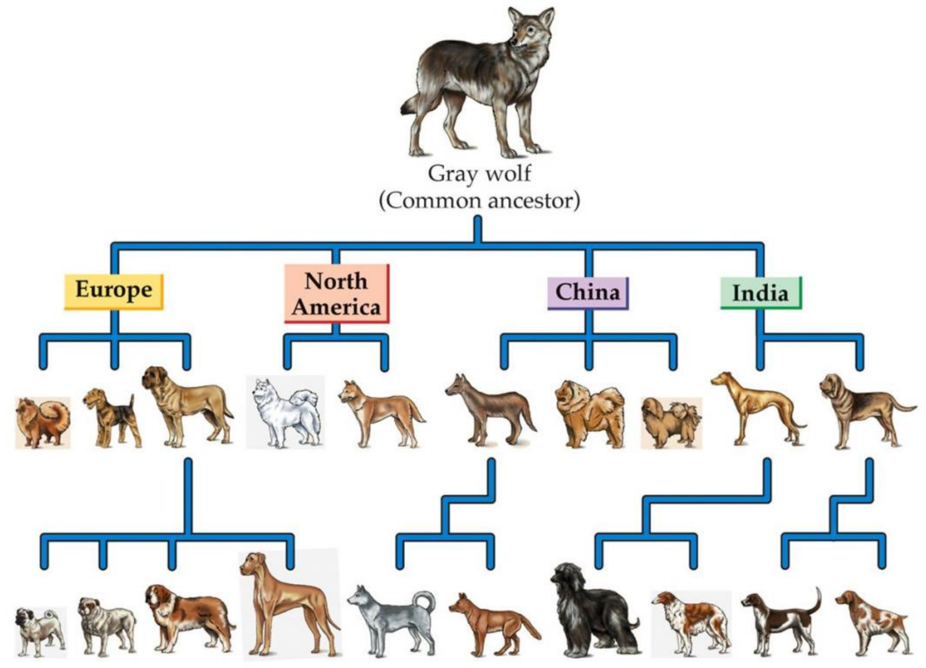

Figure 6: Artificial selection in dogs

Lecture 2:

2. Mutation

Mutation is a change in the sequence of an organism's DNA. What causes a mutation? Mutations can be caused by high-energy sources such as radiation or by chemicals in the environment. They can also appear spontaneously during the replication of DNA.

Mutations generally fall into two types: point mutations and chromosomal aberrations. In point mutations, one base pair is changed. The human genome, for example, contains over 3.1 billion bases of DNA, and each base must be faithfully replicated for cell division to occur. Mistakes, although surprisingly rare, do happen. About one in every 1010 (10,000,000,000) base pair is changed. The most common type of mistake is a point substitution. More uncommon is the failure to copy one of the bases (deletion), the making of two copies for a single base (point duplication) or the addition of a new base or even several bases (insertion). Chromosomal aberrations are larger-scale mutations that can occur during meiosis in unequal crossing over events, slippage during DNA recombination or due to the activities of transposable events. Genes and even whole chromosomes can be substituted, duplicated, or deleted due to these errors .

Mutations can have a range of effects. They can often be harmful. Others have little or no detrimental effect. Sometimes, although very rarely, the change in DNA sequence may even turn out to be beneficial to the organism.

A mutation that occurs in body cells that are not passed along to subsequent generations is a somatic mutation. A mutation that occurs in a gamete or in a cell that gives rise to gametes are special because they impact the next generation and may not affect the adult at all. Such changes are called germ-line mutations because they occur in a cell used in reproduction (germ cell), giving the change a chance to become more numerous over time. If the mutation has a deleterious affect on the phenotype of the offspring, the mutation is referred to as a genetic disorder. Alternately, if the mutation has a positive affect on the fitness of the offspring, it is called an adaptation. Thus, all mutations that affect the fitness of future generations are agents of evolution.

Mutations are essential to evolution. Every genetic feature in every organism was, initially, the result of a mutation. The new genetic variant (allele) spreads via reproduction, and differential reproduction is a defining aspect of evolution. It is easy to understand how a mutation that allows an organism to feed, grow or reproduce more effectively could cause the mutant allele to become more abundant over time. Soon the population may be quite ecologically and/or physiologically different from the original population that lacked the adaptation. Even deleterious mutations can cause evolutionary change, especially in small populations, by removing individuals that might be carrying adaptive alleles at other gene

Most mutations occur at single points in a gene, changing perhaps a single protein, and thus could appear unimportant. For instance, genes control the structure and effectiveness of digestive enzymes in your (and all other vertebrate) salivary glands. At first glance, mutations to salivary enzymes might appear to have little potential for impacting survival. Yet it is precisely the accumulation of slight mutations to saliva that is responsible for snake venom and therefore much of snake evolution. Natural selection in some ancestral snakes has favored enzymes with increasingly more aggressive properties, but the mutations themselves have been random, creating different venoms in different groups of snakes. Snake venoms are actually a cocktail of different proteins with different effects, so genetically related species have a different mixture from other venomous snake families. The ancestors of sea snakes, coral snakes, and cobras (family Elapidae) evolved venom that attacks the nervous system while the venom of vipers (family Viperidae; including rattlesnakes and the bushmaster) acts upon the cardiovascular system. Both families have many different species that inherited a slight advantage in venom power from their ancestors, and as mutations accumulate the diversity of venoms and diversity of speciesn increased over time.

Although the histories of many species have been affected by the gradual accumulation of tiny point mutations, sometimes evolution works much more quickly. Several types of organisms have an ancestor that failed to undergo meiosis correctly prior to sexual reproduction, resulting in a total duplication of every chromosome pair. Such a process created an "instant speciation" event in the gray treefrog of North America .

But somatic mutations occur in the DNA of individual cells at some time during a person's life, these changes can be caused by environmental factors such as ultraviolet radiation from the sun, mutagenic chemicals, heat, or can occur if a mistake is made as a DNA copies itself during cell division. Mutation in somatic cells (cells other than the sperm and egg) cannot be passed on the next generation. Generally mutations are the necessary raw materials of evolution .

3.Gene flow

Gene flow can be defined as the transfer of alleles or gametes from one population to another. It is also known as gene migration. When individuals of one population migrate to another population the allele frequency (the proportion of individuals carrying the same allele) of the population changes. In simple words, if individuals of population A are introduced into population B, there is a change brought about in the composition of the gene pool of population B (through interbreeding). It may also result in the addition of new variants of that allele in the population.

The rate of gene flow depends on a lot of factors, the most important being the migratory potential of the individuals of a population . In plants, the rate of gene flow depends on the effectiveness of the mechanism of dispersal of pollen and seeds used. Mate choice is also a contributing factor to gene flow as the individuals that have immigrated to the population might not find suitable mates, or the off springs (hybrids) born might not be viable, and therefore, have no effect on the allele frequency. Other factors that may affect the rate of gene flow may include the distance between the two populations, or certain physical barriers like mountains, rivers, or certain man-made structures.

Example of Gene Flow in Humans

1. In recent years, gene flow has been observed between the Caucasian population and the African-American population. African-Americans are descendants of the natives of West Africa, whereas the Caucasians are descendants of the natives of Europe. The African-American population is inherently resistant to malaria whereas, the European population isn't. The offspring produced by the mating of the individuals of these populations were seen to be resistant to the disease.

2. Another example of gene flow was during the Vietnam War, when the American soldiers mated successfully with Vietnamese women, in the 1960s and 1970s, and altered the allele frequency of the Vietnamese population.

Other Examples of Gene Flow

1. A pollen grain of a wind pollinated plant manages to fertilize some other plant to produce seed that give rise to viable offspring, and then a change in the allele frequency may be brought about.

2. Populations of moths that are white in color migrate to a population of brown-colored moths and successfully mate to give rise to viable offspring. Here, we can say that there is a change in the allele frequency. Over time, the number of these white moths will increase.

3. When the gray wolf mates with a coyote, this may give rise to viable red wolves, and therefore, a change in the number of individuals carrying a particular allele has been observed.

4. In the Atlantic cod populations, high gene flow has been observed over a large geographical area. Thus, the genetic variations between these cod populations were low.

4.Recombination

Genetic recombination happens during meiosis, special types of cell division that occur during formation of the sperm and egg cell and give them correct number of chromosomes. Inside the cells that produce sperm and egg the chromosome become paired, while they are passed together, the chromosome may break, and each may swap a portion of its genetic materials for the matching portion from its mate. This form of recombination this called crossing over .

When the chromosomes glue themselves back together on separate each has picking up new material from the other. After the chromosomes separate, they are parceled out into individual sex cells. Each chromosomes move independently of all the others a phenomenon called independent assortment. Like mutation recombination an important source of new variation for natural selection to work upon the population.

Recombination that is, new genotypes from already existing genesis of several types : (1) the production of gene combinations containing the same indi-vidual two different alleles of the same gene, or the production of heterozygous individuals (meiosis); (2) the random mixing of chromosomes from two parents during sexual reproduc-tion to produce a new individual; (3) the exchange between chromosomal pairs of particular alleles during meiosis, called crossing over, to produce new gene combinations. Chromosomal mutations such as deletion, duplication, inversion, translocation and polyploidy also result in variation.

5. Genetic drift

Genetic drift describes random fluctuations in the numbers of gene variants in a population. Genetic drift takes place when the occurrence of variant forms of a gene, called alleles, increases and decreases by chance over time. These variations in the presence of alleles are measured as changes in allele frequencies

Typically, genetic drift occurs in small populations, where infrequently occurring alleles face a greater chance of being lost. Once it begins, genetic drift will continue until the involved allele is either lost by a population or until it is the only allele present in a population at a particular locus. Both possibilities decrease the genetic diversity of a population. Genetic drift is common after population bottlenecks, which are events that drastically decrease the size of a population. In these cases, genetic drift can result in the loss of rare alleles and decrease the gene pool. Genetic drift can cause a new population to be genetically distinct from its original population, which has led to the hypothesis that genetic drift plays a role in the evolution of new species.

Examples of Genetic Drift:

1. The American Bison was hunted to near extinction and even today as the population has recovered, the result is a population of bison with little genetic variation

2. A population of rabbits can have brown fur and white fur with brown fur being the dominant allele. By random chance, the offspring may all be brown and this could reduce or eliminate the allele for white fur.

3. A mother with blue eyes and a father with brown eyes can have children with brown or blue eyes. If brown is the dominant allele, even though there is a 50% chance of having blue eyes, they might have all children with brown eyes by chance.

4. A bird may have an allele for two different beak sizes. Depending on which alleles show up in the offspring, genetic drift could cause one of the beak sizes to disappear from the population thus reducing the genetic variation of the bird's gene pool.

5. A certain type of plant can produce blue or yellow flowers. During a fire, many yellow flowers are destroyed and now since blue is the dominant allele, the plant reproduces plants that only produce blue flowers.

5.Species & speciation

- **Introduction**

On some level, the idea of a species is pretty intuitive. You don't need to be a zoologist to classify organisms like humans, giant pandas, or unflowers into groups based on their appearance. This method works well when the species in question look very different from one another. You probably wouldn't mistake a panda for a sunflower; unless you really needed your glasses!

But when we get right down to it, what really make a species a species? Organisms that look alike often belong to the same species, but this isn't always the case. On the flip side, organisms that belong to the same species can look very different from one another. For instance, dogs come in all shapes and sizes, from tiny Chihuahuas to massive Great Danes; but they all belong to the same species: ***Canis familiaris***, the domestic dog .

If appearance doesn't reliably define a species, then what does? For most eukaryotes, such as animals, plants, and fungi; scientists tend to define a species based on reproductive compatibility. That is, organisms are usually considered to be members of the same species if they can successfully reproduce with one another.

In this Lecture, we will explore how species are defined in greater detail. We'll also look at speciation, Speciation is about how species form or originated and it is important to understand evolutionary biology.

There are two patterns of speciation as evidenced by the fossil record:

1. **Anagenesis:** is the accumulation of changes associated with the transformation of one species into another, does not promote biological diversity .

2. **Cladogenesis**: branching evolution is the budding of one or more new species from a parent species. Cladogenesis promotes biological diversity by increasing the number of species .

- **The concepts of species in nature**

In biology, a species is one of the basic units of biological classification and a taxonomic rank. 'There is probably no other concept in biology that has remained as consistently controversial as the species concept'.

'What are species? Perhaps no other issue in comparative or evolutionary biology has provoked quite so much disparate opinion as this simple question'.

Many authors now apparently feel the need to come up with yet other and apparently new personal species concepts. It has identified 22 concepts to date that he recognizes as distinct, though some of us may regard many of them as essentially synonymous.

According to the most widely used species definition, the biological species concept, a species is a group of organisms that can potentially interbreed, or mate, with one another to produce viable, fertile offspring.

In this definition, members of the same species must have the potential to interbreed. However, that doesn't mean they have to be part of the same interbreeding group in real life. For instance, a dog living in Australia and a dog living in Africa are unlikely to meet but could have puppies if they did.

In order to be considered to be a single species in the biological species concept, a group of organisms must produce healthy, fertile offspring when they interbreed. In some case, organisms of different species can mate and produce healthy offspring, but the offspring are infertile, can’t reproduce.

For example, when a female horse and a male donkey mate, they produce hybrid offspring called mules. Although a mule, pictured below, is perfectly healthy and can live to a ripe old age, it is infertile and cannot have its own offspring. Because of this, we consider horses and donkeys separate species.

The biological species concept connects the idea of a species to the process of evolution. Because members of a species can interbreed, the species as a whole has a common gene pool, a collection of gene variants.

On the other hand, genes are not exchanged between different species. Even if organisms of different species combine their DNA to make offspring, the offspring will be sterile, unable to pass on their genes. Because of this restricted gene flow, each species evolves as a group distinct from other species.

The biological species concept and some proposed alternatives

1. **Biological species concept:** Emphasizes reproductive isolation. Species are groups of actually or potentially interbreeding natural populations that are reproductively isolated from other such groups.

2. **Cohesion species concept:** Focuses on mechanisms that maintain species as discrete phenotypic entities. Each species is defined by its complex of genes and set of adaptations. Applicable to organisms that reproduce without sex.

3. **Ecological species concept:** Defines species on the basis of where they live and what they do.

4. **Evolutionary species concept:** A species is a single lineage of ancestral and descendant populations that are evolving independently of other such groups.

5. **Genotypic cluster species concept:** A species is a (morphologically or genetically) distinguishable group of individuals that has few or no intermediates when in contact with other such clusters.

6. **Morphological species concept:** Defined species by measurable anatomical differences (morphological criteria). It is practical to apply in the field, even to fossils.

7. **Phylogenetic species concept:** A species is the smallest monophyletic group of common ancestry.

8. **Recognition species concept:** Emphasizes mating adaption's that become fixed in a population as individuals "recognize" certain characteristics of suitable mates.

Lecture 3

- **Reproductive isolation:**

The reproductive isolation or hybridization barriers are a collection of mechanisms, behaviors and physiological processes that prevent the members of two different species that cross or mate from producing offspring, or which ensure that any offspring that may be produced are sterile. These barriers maintain the integrity of a species over time, reducing or directly impeding gene flow between individuals of different species, allowing the conservation of each species' characteristics. There are two types of Reproductive isolation:

1. **Prezygotic**: happen before zygotes are formed.

II. Post zygotic: happen after zygotes are formed

I. Prezygotic Mechanisms:

Prezygotic mechanisms prevent interspecies mating and fertilization. There are four types of isolation that prevent mating from occurring, thus maintaining species isolation.

1. **Ecological isolation**
2. **Temporal isolation**
3. **Behavioural isolation**
4. **Mechanical isolation**
5. **Gametic isolation**

1. <u>Ecological isolation:</u>

When species occupy separate habitats or niches and do not encounter one another to reproduce due to some geographic or ecological barrier, such as ground squirrel species occupy different habitats .

2. <u>Temporal isolation</u>

When two species are found in the same area, but are incapable of mating due to different reproductive cycles for flowering or mating. Such as Red and black sea urchins live in the same location, but release their gametes at different times of the year

3. <u>Behavioral isolation</u>

Behavioral isolation when distinct mating rituals by one species may prevent members of another species from recognizing or selecting a mate. Such as male jumping spiders dance (shake their legs and wave their palps), Females of different species do not respond to the dance (**Figure17,A**). In many species, elaborate courtship displays identify potential mates of the correct species and synchronize gonadal maturation (**Figure17,B**).

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(A) **Figure 17** (B)

4. <u>Mechanical isolation:</u>

Closely related species may attempt to mate but fail because they are anatomically incompatible and transfer of sperm is not possible.

1. To illustrate, mechanical barriers contribute to the reproductive isolation of flowering plants that are pollinated by insects or other animals.

2. With many insects the male and female copulatory organs of closely related species do not fit together, preventing sperm transfer.

5. <u>Gametic isolation:</u>

Gametic isolation occurs when gametes of two species do not form a zygote because of incompatibilities preventing fusion or other mechanisms.

1. In species with internal fertilization, the environment of the female reproductive tract may not be conducive to the survival of sperm from other species.

2. For species with external fertilization, gamete recognition may rely on the presence of specific molecules on the egg's coat, which adhere only to specific molecules on sperm cells of the same species.

3. A similar molecular recognition mechanism enables a flower to discriminate between pollen of the same species and pollen of a different species.

<u>II. Postzygotic barriers:</u>

Postzygotic barriers prevent the hybrid zygote from developing into a viable, fertile adult. These barriers include: Postzygotic isolating mechanisms

4. Hybrid inviability: Development of the zygote proceeds abnormally and the hybrid is aborted. (For instance, the hybrid egg formed from the mating of a sheep and a goat will die early in development.)

5. Hybrid sterility: The hybrid is healthy but sterile. (The mule, the hybrid offspring of a donkey and a mare, is sterile; it is unable to produce viable gametes because the chromosomes inherited from its parents do not pair and cross over correctly during meiosis (cell division in which two sets of chromosomes of the parent cell are reduced to a single set in the products, termed gametes) (**Figure 18**).

6. Hybrid is healthy and fertile, but less fit, or infertility appears in later generations (as witnessed in laboratory crosses of fruit flies, where the offspring of second-generation hybrids are weak and usually cannot produce viable offspring).

Postzygotic mechanisms are those in which hybrid zygotes fail, develop abnormally, or cannot self-reproduce and establish viable populations in nature.

So species remain distinct due to reproductive isolation. But how do species form in the first place?

- **Types of Speciation**

1. Allopatric speciation: physical barrier divides population.

2. Peripatric speciation: small founding population enters isolated niche.

3. Parapatric speciation: new niche found adjacent to original one.

4. Sympatric speciation: speciation occurs without physical separation.

1. <u>Allopatric:</u>

A population splits into two geographically isolated populations for example, by habitat fragmentation due to geographical change such as mountain building) such as Darwin's Galápagos Finches (**Figure19**). The isolated populations then undergo genotypic and/or phenotypic divergence as:

1. They become subjected to dissimilar selective pressures

2. They independently undergo genetic drift

3. Different mutations arise in the two populations.

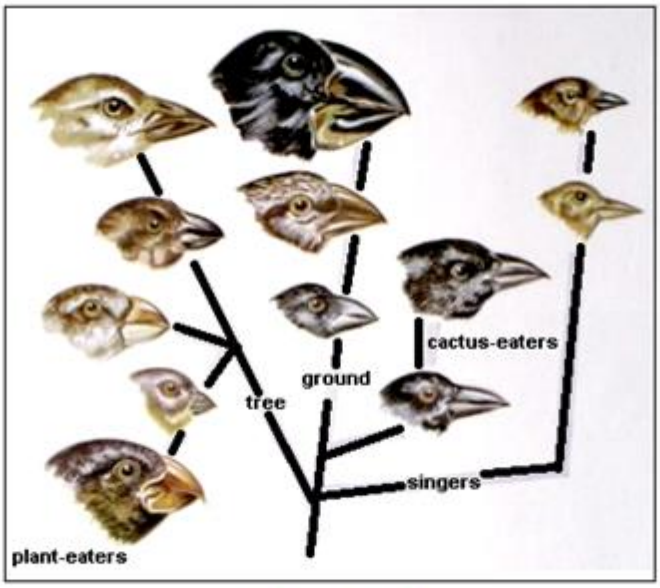

Figure 19

Ecological Niche: the role a species serves in its ecosystem including what it eats, what eats it, and how it behaves; no two species have the same ecological niche.

4. **Peripatric**:

It is a subform of allopatric speciation; new Species are formed in isolated smaller peripheral populations that are prevented from exchanging genes with the main population genetic drift proposed to play a significant role in type of speciation. **Such as** The evolution of polar bears from the brown bears is one of the best known examples of this mode of speciation.

3. Parapatric Speciation

There is only partial Separation of the zone of two diverging population afforded by geography. Such as Ensatina salamanders (**Figure20**).

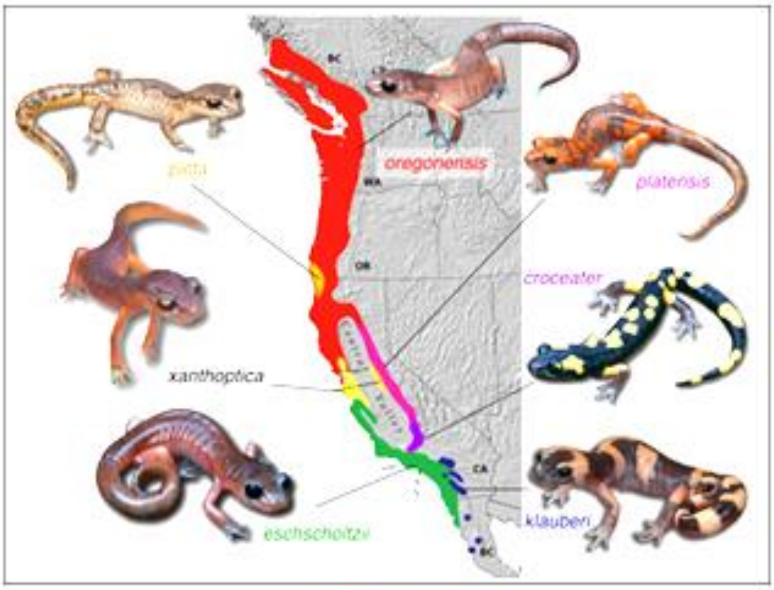

Figure 20

4. Sympatric speciation

Sympatric speciation: refers to the formation of two or more descendant species from an ancestral species all occupying the same geographic location. Often-cited examples of sympatric speciation are found in insects that become dependent on different host plants in the same area.

Polyploidy

Polyploidy is the condition of having more than two full sets of chromosomes. Unlike humans and other animals, plants are often tolerant of changes in their number of chromosome sets, and an increase in chromosome sets, a.k.a. polyploidy, can be an instant recipe for plant sympatric speciation.

How could polyploidy lead to speciation? As an example, let's consider the case where a tetraploid plant4n, having four chromosome sets suddenly pops up in a diploid population2n, having two chromosome sets. Such a tetraploid plant might arise if chromosome separation errors in meiosisproduced a diploid egg and a diploid sperm that then met up to make a tetraploid zygote. This process is shown in a general schematic below. (**Figure21**).

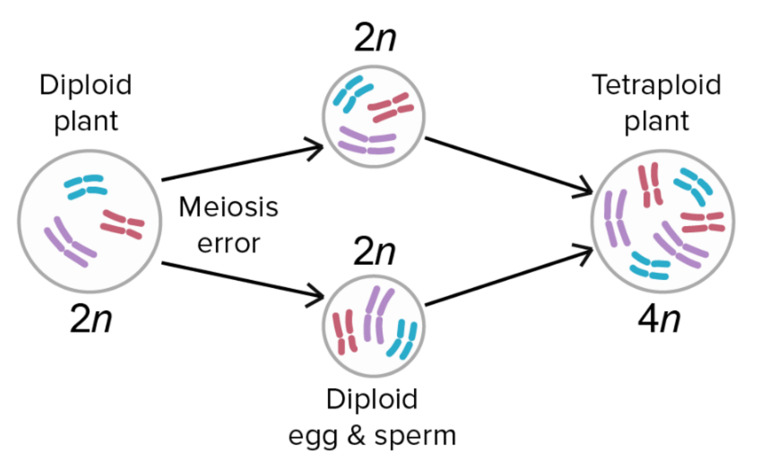

Figure21: modified from *Polyploidization*

6.Patterns of evolution

- **Introduction**

The biological evolution is defined as any genetic change in population that is inherited over several generations. These changes may be small or large, noticeable or not so noticeable.

In order for an event to be considered an instance of evolution, changes have to occur on the genetic level of a population and be passed on from one generation to the next. This means that the **genes**, or more specifically, the **alleles** in the population change and are passed on.

These changes are noticed in the **phenotypes** (expressed physical traits that can be seen) of the population.

It has been observed that the gene structure in a particular species undergoes a small-scale evolutionary change, over time. That is the reason we find different races in human beings or different breeds in dogs. This phenomenon is called **microevolution** (**Figure 22**).

Biologists believe that this process over a much larger time scale can lead to so much of genetic change that it may give rise to a new species. This theory is the extrapolation of microevolution over very long time scales. It is termed as **macroevolution** (**Figure 22**)

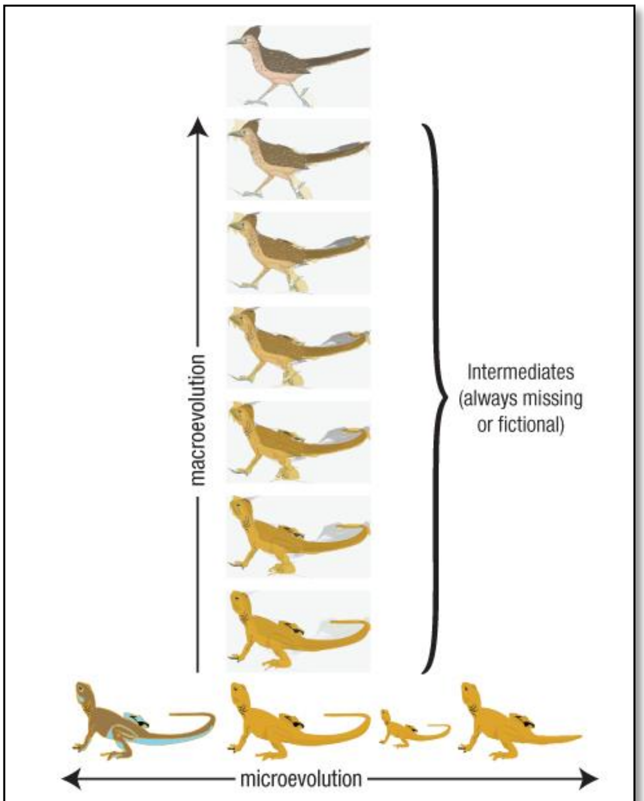

Figure 22: Macro and Microevolution

Patterns of evolution:

Evolution helps us to understand the history of life. Progressive evolution is in process, species adapt and evolve to better survive in their environments and caused changes in their traits. Similar environments can cause similar adaptation in different species, and different environments can cause different adaptation in similar species this differences lead to diversity in environment. There are five main patterns of evolution:

Divergent evolution, Convergent evolution, Parallel evolution, Coevolution, Adaptive evolution

1. Divergent evolution

Divergent evolution is when two related species are evolving to become more and more dissimilar. An example of divergent evolution is the red and the kit fox. The red fox lives in farmlands and forests where its red color easily camouflages it, as compared to the kit fox that lives on the plains and in deserts where it is also

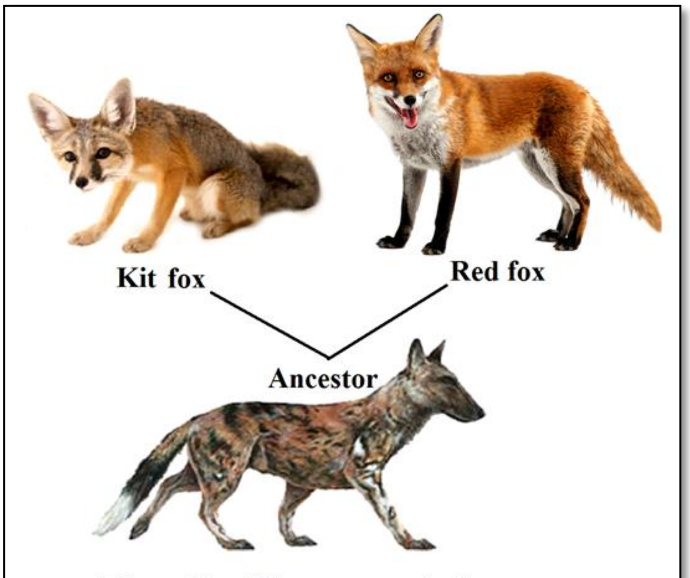

Figure23 : Divergent evolution

easily camouflaged by its sandy coloring. Also, the kit fox has larger ears as opposed to the red fox. These characteristics show a common ancestor between the two; however, they are evolving farther and farther apart. (**Figure23**)

2. Adaptive evolution

Natural selection can ultimately lead to the formation of a new species. Sometimes many species evolve from singles ancestral species. Similarities in skeletal and muscle structure of Hawaiian honeycreepers led scientist to conclude that the 23 species of Hawaiian honeycreepers evolved from one ancestor of Species. Such an evolutionary pattern in many related species evolved from single and ancestral species is called adaptive radiation adaptive radiation most commonly occur when species of organisms successfully invades an isolated region where a few competing species exist. If new habitats are available, a new species will evolve (**Figure 24**).

3. Convergent evolution

Convergent evolution is the opposite of divergent evolution. Instead of growing farther apart, two unrelated species evolve to be more and more similar. An example of convergent evolution is a cactus which grows in the American deserts and the euphorbia, which grows in African deserts. Both plants have fleshy stems loaded with spines which help the plants store water and ward off predators. (**Figure25**)

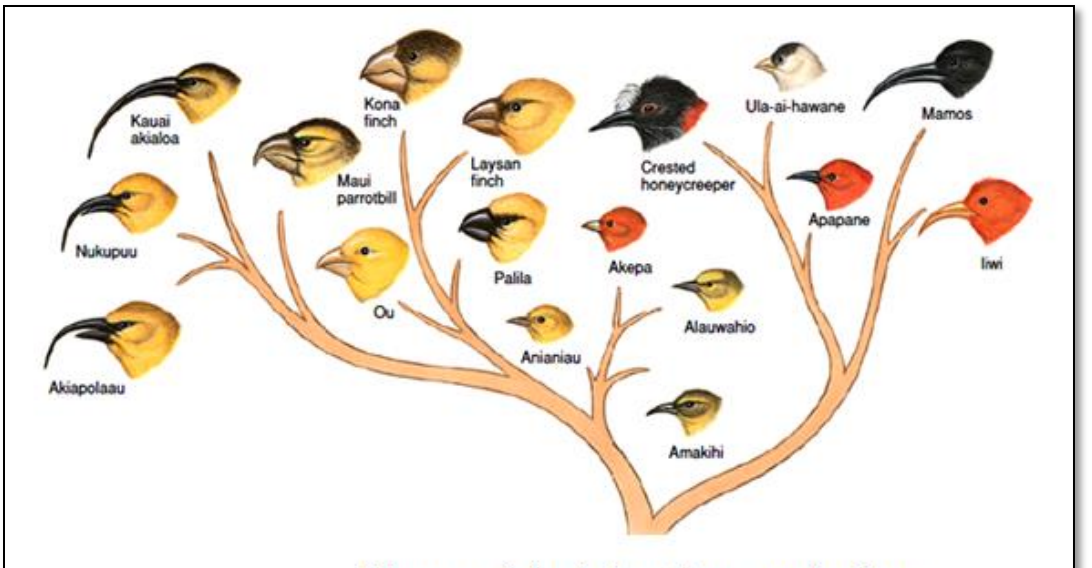

Figure 24: Adaptive evolution

Figure25: Convergent evolution

4. Parallel evolution

Parallel evolution: two or more species from similar evolutionary history continue to evolve similar characters, example: social behavior in bees, wasps, and Ants (**Figure 26).**

5. Coevolution

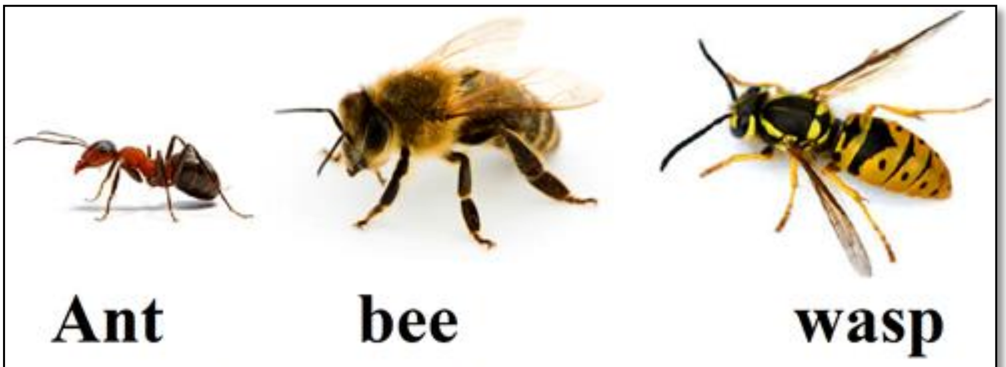

Figure 26: Parallel evolution

Coevolution is when one species evolves in response to another species evolution. While the process of coevolution generally only involves two species, multiple species can be involved. Moreover, coevolution also results in adaptations for mutual benefit. An example is the coevolution of flowering plants and associated pollinators (e.g., bees, birds, and other insect species).

Two Types of Coevolution

Coevolution is common among organisms participating in a mutual interaction. In **mutualism**, both the organisms benefit from each other. When coevolution occurs among mutually benefiting species, it is called **mutualistic coevolution**.

When coevolution is found among species that have negative effects on each other, it is called **competitive coevolution**. There are two kinds of interactions between species that can lead to competitive coevolution:

1. **Predation** is when one organism kills and eats another organism. The **prey** is the species that gets eaten by the **predator**, which is of course the species that eats the prey.
2. **Parasitism** is when one organism benefits by damaging, but not killing, another organism. The **parasite** species benefits from this relationship, while the **host** species is negatively affected.

An example of coevolution is when a plant's morphology changes, thus affecting the herbivore that eats the plant, which could affect the evolution of the plant, then the animal again, so on and so forth (**Figure27**).

Figure 27: Coevolution

Lecture 4

Biodiversity

- **Introduction**

The great variety of life on earth has provided for man's needs over thousands of years. This diversity of living creatures forms a support system which has been used by each civilization for its growth and development.

The diversity of life on earth is so great that if we use it sustainably we can go on developing new products from biodiversity for many generations. This can only happen if we manage biodiversity as a precious resource and prevent the extinction of species.

1.1:What is biodiversity?

Most straight forwardly, biological diversity or biodiversity is 'the variety of life', and refers collectively to variation at all levels of biological organization. Many more formal definitions of biological diversity or biodiversity have been proposed, which develop this simple one (DeLong 1996 reviewed 85 such definitions!).

Biodiversity is the variety of life on earth and includes variation at all levels of biological organisation from genes to species to ecosystems.

An important and widely used definition is that included within the Convention on Biological Diversity (CBD). This treaty was signed by over 150 nations at the United Nations Conference on Environment and Development, held in Rio de Janeiro, Brazil, in 1992. It defines biodiversity as "the variability among living organisms from all sources including, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

1.2: Elements or levels of biodiversity

The variety of life is expressed in a multiplicity of ways. Some sense of
this variety can begin to be made by distinguishing between different key elements. These are the basic building blocks of biodiversity. They can be divided into three groups: (i) genetic diversity; (ii) organismal diversity; and (iii) ecological diversity .

1. **Genetic diversity**

Each member of any animal or plant species differs widely from other individuals in its genetic makeup because of the large number of combinations possible in the genes that give every individual specific characteristics. Thus, for example, each human being is very different from all others. This genetic variability is essential for a healthy breeding population of a species. If the number of breeding individuals is reduced,
the dissimilarity of genetic makeup is reduced and in-breeding occurs. Eventually this can lead to the extinction of the species. The diversity in
wild species forms the '**gene pool**' from which our crops and domestic animals have been developed over thousands of years. Today the variety
of nature's bounty is being further harnessed by using wild relatives of crop plants to create new varieties of more productive crops and to breed better domestic animals. Modern biotechnology manipulates genes for developing better types of medicines and a variety of industrial products.

Few would disagree that genetic diversity is a critical component of biodiversity. This can be measured both directly (identifying and cataloguing variation in nucleotides, genes and chromosomes or indirectly (quantifying variation in phenotypic features shown – or often just assumed – to have a genetic basis).

Genes are constructed from strings of nucleotides (DNA). The total number, position and identity (there are four different types) of the nucleotides are all critical in the coding of biological information. Thus, determining nucleotide sequences is arguably one of the strongest measures of genetic diversity, although a large number of other techniques involving DNA analysis are also prevalent (restriction fragment length polymorphism (RFLP), DNA fingerprinting, random amplified polymorphic DNAs (RAPDs), microsatellite variation), their usage being dependent on the precise question being addressed.

Generally, multicellular organisms tend to have more DNA than singlecelled organisms but there are exceptions. Similarly, although there
appears to be an overall trend of increasing genome size with increasing
morphological complexity, this is not invariant. For example, the lungfish
(which still has not been fully sequenced) seems to have approximately 40 times more DNA than the mammal.

The species with the greatest amount of DNA has about 100,000 times as much as that with the least, but the species with the largest number of genes has only 20 times as many genes as that found in many bacteria. In other words, much of the variation in genomes is attributable not to differences in the number of functional genes, but in the amounts of non-coding DNA.

Until recently allelic variation determined in this way was one of the most commonly used (and cheapest) measures of genetic diversity. It was assessed using allozyme electrophoresis that identifies protein alleles, as different forms of a protein migrate at different rates on a gel. Allozyme electrophoresis has revealed an enormous amount of variation at all hierarchical levels. Genes are located on chromosomes. All eukaryotic cells contain chromosomes, and their number, size and shape in an individual is referred to as the karyotype. Variation in karyotype has been investigated in detail mainly within species of plants, insects, amphibians and mammals. Most eukaryotes possess between 10 and 50 chromosomes, but there is huge variation both within and between groupings, with the overall range being from one to more than 200 .There is no obvious relationship between chromosome number and any other measure of genetic diversity. It is difficult to see at present how the various measures of genetic diversity discussed above map onto, or relate to, other measures of biodiversity, and how they could be employed as the primary measures of biodiversity. In the former case, much of the difficulty lies in the limited understanding of how genetic diversity matches up with the results of its expression, phenotypic diversity, although great strides are being made in this area. In the latter case, the difficulty rests in the limited amount of data that are available on genetic diversity through time and space, although the quantity is growing rapidly and the means of obtaining it are becoming more rapid.

2.Species diversity

The number of species of plants and animals that are present in a region constitutes its species diversity. This diversity is seen both in natural
ecosystems and in agricultural ecosystems. At present conservation scientists have been able to identify and categorise about 1.8 million species on earth. However, many new species are being identified, especially in the flowering plants and insects. Areas that are rich in species diversity are called ‘hotspots’ of diversity. However, understanding species diversity is not

limited to recognizing the total number of species in the state. We must also consider their habitat, their range, how they meet their needs for survival, the number of individuals within each species, and how they interact with other species.

3. Community Diversity (sometimes called Ecosystem Diversity

The term ecosystem is defined as a community of living organisms combined with their associated physical environment. Ecosystems provide the "home systems" for the variety of species and microorganisms in our state. Our diverse ecosystems also provide important services that we depend on every day.

There are a large variety of different ecosystems on earth, which have their own complement of distinctive inter linked species based on the differences in the habitat. Ecosystem diversity can be described for a specific geographical region contain different species. Distinctive ecosystems include landscapes such as forests, grasslands, deserts, mountains, etc., as well as aquatic ecosystems such as rivers, lakes, and the sea. Each region also has man-modified areas such as farmland or grazing pastures.

An ecosystem is referred to as 'natural' when it is relatively undisturbed by human activities, or 'modified' when it is changed to other types of uses, such as farmland or urban areas. Ecosystems are most natural in wilderness areas. If natural ecosystems are overused or misused their productivity eventually decreases and they are then said to be degraded. India is exceptionally rich in its ecosystem diversity.

1.3: How many extant species are there?

If the diversity of life has increased through evolutionary time, how many species are presently extant? Although it has received substantial attention, the importance of this question perhaps has less to do with the usefulness of the actual answer than with the challenge it poses to an understanding of how biodiversity is distributed amongst different groups of organisms and across the Earth. It is one of the basic descriptors of life on the planet, to which we should be able to provide a reasonably accurate answer. On the face of it, the best way of finding out how many extant species there are would simply be to count them! However, the diversity of life is so great that this presents a truly formidable task, and one that has never risen high enough up the agenda of humankind to be given serious consideration. The question of how insurmountable the obstacle would be if substantial resources, technology and ingenuity were brought to bear decades, but most are unconvinced. Given the enormity of such a task, all of the many attempts at estimating how many extant species there are have employed indirect measures, and, in the process, have made major assumptions of one kind or another. Five main methods have been used to estimate the numbers of extant species in large taxonomic groups or all groups, based on extrapolations from:

1 *Canvassing experts*. This involves estimating overall numbers of species based on the opinions of those experts who have studied particular groups of species over long periods and have gained an understanding of the numbers that are unknown to science. This makes the entirely untestable assumption that these experts know these groups sufficiently well to make reliable estimates.

2 *Patterns of species description*. Overall numbers of species in some groups have been estimated by extrapolating into the future the growth in the cumulative numbers of taxonomically described species through time. This assumes that past patterns of description indicate future patterns.

3 *Proportion of undescribed species*. This approach involves estimating overall numbers of species from the ratio of previously unknown to previously known species in large samples of specimens, and then extrapolating from the overall numbers of known species. This assumes that the samples are representative.

4 *Well-studied areas*. Overall numbers of species globally or in very large regions have been estimated by extrapolating from those few (predominantly temperate) areas for which numbers of species are reasonably well known. This assumes that the areas for which overall species numbers are well known are representative of those for which they are not.

5 *Well-studied groups*. This involves estimating overall numbers of species based on the global numbers in well-known groups and estimates of the ratio of the numbers of species in these groups to others in those few regions where the latter are reasonably well known. This assumes that these ratios of numbers of species in well-known and other groups remain reasonably constant across space.

The assumptions of all of these approaches are seldom precisely met. All

also require extrapolation beyond the bounds of available data, something
that statisticians, quite correctly, always caution against.

A widely quoted working estimate of extant species numbers, integrating what is presently known based on large numbers of studies, is one of around 13.5 million, with upper and lower estimated numbers of about 3.5 and 111.5 million species, respectively. The upper boundary appears wildly improbable if for no other reason than that it is not obvious where all the 'missing' species are to be found! Evidence in support of the working estimate or a figure somewhat lower is becoming increasingly convincing, albeit categorical demonstrations of its validity do not exist. Thirteen and a half million species is difficult to visualize. It is about one species for every 450 people in the world, but it is debateable how much that helps to comprehend this extraordinary level of diversity.

The major uncertainties in the overall numbers of species remain in estimates for particular taxonomic groups (e.g. viruses, bacteria, fungi, nematodes, mites, insects), functional groups (e.g. parasites), and habitats or biomes (e.g. soils, tropical forest canopies, deep-ocean benthos; Indeed, the relative contribution of some groups compared with others continues to be, sometimes vigorously, debated

• *Bacteria*. Understanding of the numbers of species of bacteria (and microbes more generally) is complicated by frequent difficulties in applying standard species concepts to these creatures (resort is usually made to operational taxonomic units, OTUs), by the difficulty of culturing the vast majority of these organisms and thereby applying classical identification techniques, and by the unimaginable numbers of individuals that exist (the global number of prokaryotes is estimated to be 4–6 × 1030 cells, with a production rate of 1.7 × 1030 cells yr−1 . The numbers of species estimated to occur in even very small areas can vary by several orders of magnitude, depending on the approach taken to estimation. Globally, it is clear that the diversity of bacteria, both in terrestrial and marine systems, may be far larger than many had previously imagined, and may number millions of taxa.

• *Protozoa.* Whilst even very small samples of sediment may contain many species of Protozoa, it is becoming clear that at least in some groups most of these have large geographic ranges and that this local richness may not therefore be indicative of high global richness. Thus, of 85 ciliate species found in a volcanic crater-lake in Australia none were unique to the continent . Free-living ciliate species have been estimated to perhaps number just 3000, with the number of extant free-living Protozoa totalling perhaps 12,000–19,000.

• *Fungi*. A working figure of 1.5 million species of fungi, based primarily on extrapolation from temperate studies. On the one hand, some tropical studies suggest that this may constitute a substantial underestimate . On the other hand, it has been argued that the frequency of discovery of previously unknown species in areas whose fungi are not well studied suggests that the figure may be a substantial overestimate. Regardless, the scale of fungal diversity may be suggested by the discovery that just three individual plant leaves (two dicotyledonous and one palm leaf) from the Neotropics together supported 108 foliicolous lichen species, 25% of all the taxa known from the region , lichens comprise a mutualistic relationship between a fungus and an alga or cyanobacterium.

• *Nematodes*. Cobb (1914) observed that 'If all matter in the universe except the nematodes were swept away, our world would still be dimly recognisable, and if, as disembodied spirits, we could then investigate it, we should find its mountains, hills, vales, rivers, lakes and oceans represented by a film of nematodes'. Figures of 1 million to 100 million
extant species have been suggested, although recent analyses have cast severe doubt on the more extreme upper estimates.

• *Insects.* The total number of all species depends in major part on the number of extant species of insects (because they constitute such a high proportion of all species), for which estimates have ranged particularly widely. A number of recent analyses have strongly suggested that the higher estimates are not tenable ,but they continue to be championed in some quarters. Much of the uncertainty rests on the numbers of species that are to be found in the tropical rain forest canopy, the proportion that are restricted to this environment, and the degree of host specificity of herbivorous insects in such forests, which was assumed to be much higher than is actually the case, implying a fine subdivision of plant resources and thereby inflating estimated numbers of insect species .Debate continues tosurround the issue of which order of insects is most speciose. Evidence that the Coleoptera (beetles) are a more tropical group than some of the others would seem to bolster their claim, but empirical support is quite sparse. A feature common to most of these groups is that many of their species are parasites. This has led to a lively debate as to whether parasitism is the most common lifestyle on Earth, and whether the majority of species are parasitic rather than free-living . Given that parasites are, and will doubtless remain, more poorly known than free-living species, these are important issues in understanding the overall biodiversity of life on Earth. Given that most free-living species harbour many species of parasites, that some of these species are commonly host specialists, and that parasites frequently themselves provide hosts for other parasites, the significance of the parasitic way of life to the global total number of species is indisputable. If you remain unconvinced, then consider that humans alone play host to probably several hundred parasitic species (including microbes).

Significant debate over numbers of extant species also persists for some of what are regarded as better known taxonomic groups. Thus, for example, it appears that the widely quoted figure of c. 250,000 species of angiosperms (seed plants) is a substantial underestimate, with suggestions that there may in fact be 300,000 or even more than 400,000 . 1.75 million living species have been described, that is about 13% of an estimated total number of extant species of 13.5 million, with the percentage of species in some particular groups that have been described thought to be much smaller .

Lecture 5

Relationships between two Species

The populations can be very much affected by the interactions between the organisms in the environment. The major types of interactions are discussed below:

1.Mutualistic Interactions and Symbiotic Relationships

Symbiosis means “living together.” Usually the term is used only to describe pairs of organisms that live together without harming one another, thereby excluding parasitism (+, –) and amensalism (–, 0), in which one party is affected adversely.. Hence, symbiotic relationships include mutualism (+, +), commensalism (+, 0), and neutralism (0, 0). Obligate mutualisms can be distinguished from facultative ones. As pointed out before, these various types of interactions can change in evolutionary time and grade into one another.

Although mutualism is a symmetric relationship, there may nevertheless usually be an asymmetry in costs versus benefits to each of the parties concerned (a conflict of interests arises even in mutualistic relationships!). Mutualisms may evolve from As pointed out earlier, true neutralism is uninteresting as well as uncommon and therefore need not be considered. However, mutualism and commensalism are fairly widespread, particularly in diverse communities. Many organisms have

formed mutualisms with ants. For example, the bullhorn *Acacia* supports a colony of ants, feeding them both nectar and protein; the ants in turn protect the plant from a wide variety of herbivores (when ants are removed by poisoning them, these plants are quickly defoliated).

Likewise, caterpillars in many different Lepidopteran families have evolved close mutualisms with ants to defend themselves against parasites and predators . These caterpillars “sing” to the ants as well as feed them a nutritious proteinrich diet .. Numerous other cases are also known. In many legumes such as mesquite, root nodules house bacteria that fix atmospheric nitrogen. Mycorrhizae, or fungal roots, supply mineral nutrients to host plants but in return gain organic carbon from the host. Many deep-sea fish harbor bioluminescent bacteria, exploiting their light-emission abilities to the fish’s own ends in the dark depths of the oceans. Certain types of algae are endozoic, actually living inside the cells of animal hosts, particularly coelenterates such as corals and *Hydra*

. In these situations, algal photosynthate is shared with the host. Some invertebrate “hosts” actually digest away most of the alga, retaining (“kidnapping”?) just the chloroplasts, which continue to photosynthesize inside the animal. Perhaps the ultimate in mutualistic interactions concerns the intriguing theory of endosymbiosis; very strong evidence exists that certain of the cell organelles found in higher organisms (eukaryotes), particularly chloroplasts and mitochondria, are actually the remnants of symbiotic prokaryotic organisms that have been permanently incorporated into the eukaryotes. Because most land plants cannot move, they often exploit animals both for pollination and for seed dispersal (some rely on wind, too). Seeds of many fruits pass unharmed through the intestines of herbivores and germinate to grow a new plant from the droppings of the animal dispersing agent. Colorful flowers with nectar and brightly colored fruits can only be interpreted as having been evolved to attract appropriate animals. Obligate mutualisms are less common than facultative ones, probably because both populations depend completely on the relationship and neither can survive without the other. A very high degree of interdependency occurs between figs and the agaonid fig wasps that pollinate them (wasp eggs are laid inside fig fruits where larvae develop). There are hundreds of species of figs, each with its own species of wasp (this is a good example of tight, or species-specific, coevolution). Similarly, termites cannot themselves produce enzymes to digest the cellulose in wood, but by harboring in their intestines a population of protozoans that can make such enzymes, the insects are able to exploit wood successfully as a food source. Neither termite nor protozoan could survive without the other. These intestinal endosymbionts are passed on from one generation of termites to the next through exchange of intestinal contents. Large grazing mammals have a rumen in their gut system, an anaerobic chamber that houses endosymbiotic protozoans and bacteria, which similarly assist in digestion. Another putative example of mutualism is lichens, which are composed of a fungus and an alga; the fungus provides the supportive tissue, whereas the alga performs photosynthesis. (Algae of some lichens can be grown without the fungi.)

Commensalism occurs when one population is benefited but the other is unaffected (+, 0). Small epiphytes such as bromeliads and orchids, which grow on the surfaces of large trees without obvious detriment to the tree, might be an example. A well documented case of commensalism is the association between cattle egrets and cattle .). These egrets follow cattle that are grazing in the sun and capture prey (crickets, grasshoppers, flies, beetles, lizards, frogs) that move as cattle approach. The number of cattle egrets associated with cattle is strongly dependent on the activities of the cattle; thus, Heatwole observed fewer egrets than expected on a random basis near resting cattle, but nearly twice as many egrets as expected (if the association were entirely random) accompanied cattle that were actively grazing in the sun. Since the birds seldom take prey (such as ticks and other ectoparasites) directly from the bodies of the cattle, the mammals probably benefit little from their relationship with egrets. Moreover, egret feeding rates and feeding efficiency are markedly higher when these birds are associated with cattle .

2.Competition

Competition (–, –) takes place when each of two populations affects the other adversely. The process competition is thought to be a part of daily life. Competition is a relationship in which different organisms or populations in the ecosystem attempt to use the same limited resources at the same time. The limiting resource may be water, prey, light, water etc, which is responsible for the organism's growth and survival in the ecosystem. Competition can occur both within (intra specific) and between (inter specific) species. An individual experiences both types of competition, but the range of the competitions varies widely from population to population and species to species. Competition among the individuals can also be characterized as resource competition or interference competition. The resource competition is characterized by the organism's completion directly for the limiting nutrient in the ecosystem, there by obtaining as much each individual can. An example is the competition of fly maggots in a mouse carcass, where few individuals obtain enough nutrients for their reproduction and survival. Resource competition may not always cause the exclusion of one species instead some species can coexist, with a marked reduction in their growth potential capabilities. In interference competition, the individuals harm each other directly by a physical force. In this case either the individuals interact with foraging, survival, and reproduction of others or directly prevent their physical organization in a part of their habitat. An example is the physical intimidates of caterpillar to other. Interference competition generally results in the exclusion of one of the two competitors.

Early in the 20th Century, A.J. Lotka and V. Volterra developed a model for population growth, which explains that two species cannot compete for the same limiting resource for a long period. This is known as Competitive exclusion principle. G.F.Gausse, a Russian ecologist, demonstrated that Paramecium aurellia competes and later displaces Paramecium caudatum which apparently confirmed the Competitive exclusion theory. Recent studies showed the coexistence of some killer particle in Gausse's strain P. aurellia is responsible for such an outcome. Later Thomas Park showed that due to interference competition, the confused flour beetle and the red flower beetle would not coexist and hence one species always excluded the other.

3.Predation

Predation (+, –) occurs when one population affects another adversely but benefits itself from the interaction. Usually a predator kills its prey and consumes part or all of the prey organism. An organism which feeds on another organism for their food is called predator while the organism that is fed upon is termed as the prey. This kind of interaction between the prey and predator is known as predation. Typically a predator tends to be larger than that of the prey, and hence they consume many preys during their life cycle. During the act of predation often the death of prey will occur due to the absorption of the prey's tissue by the predator . Typical examples of predation are bats eating the insects, snakes eating mice, and the whales eating the krill.

In the case of some complex food webs, a predator can also become a prey for the species. Most of the organisms in the ecosystem evolved some kind of defense mechanisms against the predations.

4.Parasitism

Parasitism (+, –) is essentially identical to predation, except that the host (a member of the population being adversely affected) is usually not killed outright but is exploited over some period of time. Thus, parasitism can in some ways be considered as a "weak" form of predation. A parasite feeds on the host, but they generally do not destroy it. Parasites are usually smaller then the host. Parasites may have more than one host during its life cycle. The host evolved some defense mechanisms against the parasites; the most important is the immune responses such as cellular defenses. Also parasites can substantially decrease the host population sizes. The relationship between the parasites and the hosts is known as

Parasitism. Tapeworms, blood sucking leeches and tape worms are typical examples of parasites .

Lecture 6

Extinction of species

- **Introduction**

The overall pattern of temporal change in biodiversity results from the difference between rates of speciation (adding species) and rates of extinction (taking species away). If species are being generated faster than they are becoming extinct, then the level of biodiversity will rise. When the rate of extinction equals that of speciation an overall pattern of stability (stasis) will result. Hence if, or when, stasis is observed biodiversity this does not necessarily mean that nothing is happening; turnover in the identities of taxa through time could, and frequently will, still be high. When the level of extinction exceeds that of speciation then biodiversity will decline, and if this persisted for a sufficient period then life would ultimately be expunged from the Earth.

Over the history of life on Earth, in excess of 90% of all species (and perhaps closer to 98%) are estimated to have become extinct. Based on evidence from a variety of groups (both marine and terrestrial), the best present estimate is that the average species has had a life span (i.e. from the time a particular species appears in the fossil record until the time it disappears) of around 5–10 Myr .

Some groups tend to have characteristically higher rates of extinction than do others. Thus, there is substantial variation in the estimated periods for which, on average, species in different taxonomic groups persist . Indeed, natural extinctions tend to be taxonomically clumped, often disproportionately within species-poor groups, which may mean that more genetic diversity is lost than would be expected by chance.

- ✓ **Endangered Species**

An endangered species is a population of organisms which is at risk of becoming extinct because it is either few in numbers or threatened by changing environmental or predation parameters. Many nations have laws offering protection to conservation-reliant species, for example, forbidding hunting, restricting land development or creating preserves. Only a few of the many species is at risk of extinction actually make it to the lists and obtain legal protection like pandas. Many more species become extinct or potentially will become extinct, without gaining public notice.

- ✓ **Human impacts on biodiversity**

Although it is essential to humankind, brings innumerable benefits, and has other important values, humans have had strong negative impacts on biodiversity. Indeed, whilst over geological time the general trend has been towards an overall net increase in biodiversity, the late Quaternary has been a period of marked decline, as both a direct and indirect consequence of human activities. This decline comprises all those changes that are associated with reducing or simplifying biological heterogeneity, from genes to ecosystems.

In this lecture we consider the negative human impacts on biodiversity, concentrating particularly on the loss of species. First, we address the level of those losses .). Second, we examine the four principal proximate causes of the losses, namely overexploitation, habitat loss and degradation, introduced species, and extinction cascades . Third, we consider the ultimate causes of the impacts of humans on biodiversity, namely the size of the human population, the growth in that population, and the scale of the human enterprise .

- ✓ **Loss of biodiversity**

Humans have increased the species extinction rate by as much as 1,000 times over background rates typical over the planet's history. 10–30% of mammal, bird, and amphibian species are currently threatened with extinction . If we assume that there are around 14 million species on Earth at present, then each year the tree of life grows by an extra 14 Myr of branch length. The average age of extant species is nearly 5 Myr (this data is from primates and carnivores, species in other groups may well be older). So the tree can 'afford' at most about three species extinctions per year without shrinking overall. There have been roughly this many documented species extinctions per year since 1600 and many extinctions will not have been documented. Last century saw the extinction of 20 mammalian species, a pruning of the mammalian tree that would require at least 200 centuries to redress. The largest assessment of the effect of humans on the Earth's ecosystems was started in 2000 and called the Millennium Ecosystem Assessment (MEA). It found that over the past 50

years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history and that this has resulted in a substantial and largely irreversible loss in the diversity of life on Earth. It stresses that the loss of species and genetic diversity decreases the resilience of ecosystems, and that human impacts such as over-harvesting, climate change, invasive species, and nutrient loading push ecosystem toward thresholds that they might otherwise not encounter (MEA 2005).

Causes of biodiversity loss

The Millennium Ecosystem Assessment identifies habitat change, climate change, invasive species, over-exploitation and pollution as the primary drivers leading to loss of biodiversity .

1. Habitat change

Humans have had an effect on every habitat on Earth, particularly due to the conversion of land for agriculture. Cultivated systems (areas where at least 30% of the landscape is in croplands, shifting cultivation, confined livestock production, or freshwater aquaculture) now cover one quarter of Earth's terrestrial surface. Habitat loss also occurs in coastal and marine systems, though these changes are less well documented. Trawling of the seabed, for instance, can significantly reduce the diversity of benthic habitats. Dramatic reshaping of the distribution of habitats or vegetation types has been a feature of much of the history of humankind, with habitat change as a consequence of the activities of prehistoric populations having been reported on numerous occasions . Indeed, it has repeatedly been discovered that what had been held to be 'natural' landscapes had actually been much transformed by earlier human activities . At a broad scale, compared with an estimation of their extent before significant human disturbance, forest/woodland has declined in area by 29%, steppe/savannah/grassland by 49%, shrubland by 74%, and tundra/ hot desert/ice desert by 14%. Cropland now covers 11% of the land surface, and pasture 23%. Human disturbance is evident in every biome on Earth, and in terrestrial systems is most marked in temperate broadleaf and evergreen sclerophyllous forests . Perhaps some of the most graphic evidence of such changes comes from contrasting the extent of the most speciose terrestrial environment, tropical forest, at different times, in particular areas of the world . Most such forest clearance arises from pressures that are external to the ecosystem, particularly an undervaluing of the forest resource that encourages liquidation of the natural capital it provides and its replacement with agricultural systems that yield quicker returns). This situation is acute in regions where immediate needs predominate, and future income is discounted at a high rate. As predicted from species–area relationships land-use changes have brought about the loss of many species, and are the primary cause of species being listed as at high risk of extinction in the near future. Thus, globally 71% of freshwater fish species (excluding Lake Victoria cichlids, because of the complexity of their situation) that have recently become extinct have apparently done so for this reason , and 85% of bird and 47% of mammal species (not including most of the small mammals, because of insufficient data) are listed as being at risk on the same grounds. More than 100 species of birds are at threat as a result, at least in part, of each of 13 causes of habitat loss: selective logging / cutting, smallholder farming, plantations, clear-felling, arable farming/ horticulture, livestock farming, infrastructure development, human settlement, grazing, shifting agriculture, deforestation with unknown causes, timber (firewood), and mining . Substantial land-use change is predicted to continue into the future, not simply as a consequence of direct human activities, but also as a consequence of anthropogenic global climate change.

2. Climate change

Observed recent changes in climate, especially warmer regional temperatures, have already had significant impacts on biodiversity and ecosystems, including causing changes in species distributions, population sizes, the timing of reproduction or migration events, and an increase in the frequency of pest and disease outbreaks. By the end of the twenty-first century, climate change and its impacts are likely to be the dominant direct driver of biodiversity loss and changes in ecosystem services globally .

3. Invasive Species

The spread of invasive alien species has increased because of increased trade and travel. While increasingly there are measures to control some of the pathways of invasive species, for example, through quarantine measures and new rules on the disposal of ballast water in shipping, several pathways are not adequately regulated, particularly with regard to introductions into freshwater systems .

4. Overexploitation

For marine systems, the dominant direct driver of change globally has been overfishing. Demand for fish as food for people and as feed for aquaculture production is increasing, resulting in increased risk of major, long-lasting collapses of regional marine fisheries. 50% of the world's commercial marine fisheries are fully exploited whilst 25% are being overexploited. For example, the Atlantic cod stocks off the east coast of Newfoundland collapsed in 1992, forcing the closure of the fishery, the depleted stocks may not recover even if harvesting is significantly reduced or eliminated .

5. Pollution (especially nutrient loading)

Since 1950, human mediated increases in nitrogen, phosphorus, sulphur, and other nutrients (nutrient loading) has emerged as one of the most important drivers of ecosystem change in terrestrial, freshwater, and coastal ecosystems, and this driver is projected to increase substantially in the future. For example, humans now produce more biologically available nitrogen than is produced by all natural pathways combined. Aerial deposition of reactive nitrogen into natural terrestrial ecosystems, especially temperate grasslands, shrub-lands, and forests, leads directly to lower plant diversity; excessive levels of reactive nitrogen in water bodies, including rivers and other wetlands, frequently leads to algal blooms and eutrophication in inland waters and coastal areas (figure 9). Similar problems have resulted from phosphorus, the use of which has tripled between 1960 and 1990. Nutrient loading will become an increasingly severe problem, particularly in developing countries and particularly in East and South Asia.

6. **Introduced species**

Since prehistoric times, human actions have served, intentionally or accidentally, to introduce non-domesticated species to areas in which they would not naturally have occurred, breaching many natural barriers to their dispersal. Ignoring domesticated species, the earliest known instance involves the introduction of a marsupial, the gray cuscus *Phalanger orientalis*, to New Ireland about 19,000 years ago . Perhaps some 400,000 species have now been introduced. Often these constitute a high proportion of the species that occur in a given area, and they continue to grow in number . Introduced species are now widespread even in many nature reserves . Such movements of species have been brought about by a multiplicity of routes, including intentional introduction for cultivation or sport, the transport of soil and ballast, the connection of waterways through canals, and the release or escape of pets. They reflect our choices as consumers, travellers, gardeners, and so on. Not infrequently, the numbers of introduced species in an area increase with the size of the human population, the duration of human occupation, and the numbers of visitors, all of which tend to increase the levels of such activities, and hence the likelihood and frequency with which individuals of given species arrive . The numbers of introduced species in an area tend also commonly to be positively related to the number of native species, probably because the successful establishment of species of both groups responds to similar factors (. Some introductions have enriched human existence and most invaders have minor consequences; .Introduced species can alter nutrient regimes, fire regimes, hydrology, or energy budgets, change vegetation or habitat, and drive changes in the abundance and distribution of native species, ultimately to extinction. Drawn from a wide diversity of groups , they have thus become major agents of global change. Nearly a half of the threatened species of the USA, for example, are at risk at least in part because of the effects of alien species. Introduced species have most frequently caused species extinctions through predation/parasitism. Perhaps some of the best-documented examples have concerned the introduction of exotic predators to lakes and islands and the consequent extinction of plants and animals that had evolved no defences against them. Thus, numbers of species of fish, many endemic, from the lakes of the East African Rift Valley may be extinct as a result of the intentional introduction of the Nile perch *Lates niloticus*, a voracious predator (although other factors have also contributed;. Likewise, the accidental introduction of the brown tree snake *Boiga irregularis* to the island of Guam around 1950 resulted, directly or indirectly, in the loss of perhaps 12 species of an original fauna of 22 native birds (three pelagic species and perhaps nine forest ones, some endemic to the island), the reduction of most of the remaining forest species to small remnant populations, and the loss of 3–5 species of an original fauna of 10–12 reptiles . In both cases, the catholic tastes of the generalist predators involved has been important, enabling them to maintain high abundances even when one of their prey species has been driven scarce. The potential for introduced species to predate native species highlights the need for great caution in employing biological control of pest species. Whilst this can be exceedingly beneficial in economic terms, potential biological control agents need to be very carefully screened to ensure that they will not have negative impacts on other species.

7. Extinction cascades

The extinction of one species may lead to the extinction of others. Indeed, this is inevitable where this species provides critical resources for others, such as specialist herbivores, parasites or predators, or perhaps itself acts as a specialist pollinator or dispersal agent. Thus, for example, in New Zealand, the giant eagle *Harpagornis moorei* almost certainly preyed on the large flightless moas, and its extinction likely resulted when these declined in numbers as a result of the hunting by the Maori that led to their demise. More complex sets of interactions may also result in cascades of extinctions, as evidenced by the dramatic, and often extensive, changes in floral and faunal composition that can result from changes in the abundance and occurrence of key species (e.g. large-bodied predators and herbivores; For example, the loss of large bodied predator species may be accompanied by meso-predator release, in which somewhat smaller predators escape the population controls that were previously imposed on them, and as a result they exert increased predation pressure on their prey species, reducing their abundance and perhaps driving them locally or even globally extinct.

Lecture 7

Importance of biodiversity

- **Introduction**

Humans cannot exist without biodiversity as we use it directly and indirectly in a number of ways . Direct use includes things like food, fibres, medicines and biological control, whilst indirect uses includes ecosystem services such as atmospheric regulation, nutrient cycling and pollination. There are also non-use values of biodiversity, such as option value (for future use or non-use), bequest value (in passing on a resource to future generations), existence value (value to people irrespective of use or non-use) and intrinsic value (inherent worth, independent of that placed upon it by humans) . Many of these uses of biodiversity are not incorporated in economic accounts and this leads humans to under-value biodiversity. Ecosystem services and resources such as mineral deposits, soil nutrients, and fossil fuels are capital assets but traditional national accounts do not include measures of the depletion of these resources. This means a country could cut its forests and deplete its fisheries, and this would show only as a positive gain in GDP (grossnational product) without registering the corresponding decline in assets (wealth) .The relationship between biodiversity and ecosystem function is clear but a major question in ecology is how much biodiversity is required to maintain ecosystem function.

1. Direct-use value

Direct-use value derives from the direct role of biological resources in
consumption or production. It essentially concerns marketable commodities. The scale of the direct-use exploitation of biodiversity is enormous and extremely multifaceted. To date it has eluded comprehensive evaluation. Under some broad headings, selected types of the direct-use value of biodiversity are for food, medicine, biological control, industrial materials, recreational harvesting and ecotourism. We will address each of these in turn.

1.1 Food

Biodiversity provides food for humans, and hence is the foundation of all our food industries and related services. This food takes forms that include vegetables, fruit, nuts, meat, and adjuncts to food in the form of food colourants, flavouring and preservatives. These may derive from wild or cultivated sources, but for the bulk of the human population the latter are, of course, predominant (in 1997, global agriculture provided 95% of all plant and animal protein and 99% of energy consumed by Humans. Of the 300,000 or more species of flowering plants, about 12,500 are considered to be edible to humans. Average global annual production of major food crops in 1996–98 totalled 2.7 billion tonnes (2.07 billion tonnes of cereals and 0.64 billion tonnes of roots and tubers; United Nations Development Programme et al. 2000). Global fisheries land more than 80 million tonnes per year.

1.2 Medicine

As well as providing sustenance, biodiversity plays other vital direct roles in maintaining the health of the human population. Natural products have long been recognized as an important source of therapeutically effective medicines, and more than 60% of the world's human population relies almost entirely on plant medicine for primary health care. Of 520 new drugs approved between 1983 and 1994, 39% were natural products or were derived from them. Moreover, of the 20 bestselling non-protein drugs in 1999, nine were derived, directly or indirectly, from natural products, with combined annual sales of more than US$16 billion . Animals also are extensively used in traditional remedies (with international trade in association with Oriental and other customary forms of medicine being substantial), as a source of a range of products in modern medicine (e.g. anticoagulants, coagulants, vasodilatory agents) and for models on which to test potentially useful drugs or techniques.

1.3 Biological control

The use of natural enemies to control species regarded as problems is increasingly widespread and is often seen as an environmentally friendly alternative to the use of pesticides .Biocontrol programmes have been attempted against several hundred species of plants and insects, with approximately 30% of weed biocontrol and 40% of insect biocontrol programmes being successful. Biological control has included introductions of agents to control populations of pests in or on crops, populations of disease vectors (e.g. mosquitoes) and populations of invasive species.

1.4 Industrial materials

A wide range of industrial materials, or templates for the production of such materials, have been derived directly from biological resources. These include building materials, fibres, dyes, resins, gums, adhesives, rubber, oils and waxes, agricultural chemicals (including pesticides) and perfumes. For wood alone, in 1989 the total worldwide value of exports was estimated to be US$6 billion, and more than 3.8 billion cubic metres are estimated to be harvested annually worldwide, for fuel, timber and pulp.

2. Indirect-use value

The biota annually cycles gigatonnes (1015 g) of elements such as carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur, and teragrams (1012 g) of aerosols and particles among the atmosphere, hydrosphere (the waters) and lithosphere (the solid matter forming the Earth's crust; . Such biogeochemical cycling modifies physical and chemical conditions, creating an environment that sustains life. Indeed, in the absence of life, Earth would be a very different place. In particular, it has been estimated that the atmospheric gas composition would be radically altered, and surface temperatures and pressures dramatically heightened. The indirect-use value of biodiversity derives from the many functions that it performs in providing services that are crucial to human wellbeing .

These services can in some sense be regarded as being 'free', in that they tend not to be the subject of direct trading in the marketplace, although such a perception has proven detrimental to their maintenance. Alongside those that are perhaps more readily recognized, such as nutrient cycling and soil formation, there are numerous other ecosystem services. For example, many non-commercial species of marine mollusks and crustaceans may not be used directly themselves, but may nonetheless constitute an essential food source for many economically important fish species. The value of these invertebrates is indirect as they derive their value (in an economic sense) from the fish. Likewise, declines in the diversity and numbers of wild bees in many areas (often as a product of habitat destruction) have drawn attention to their agricultural significance as pollinators, and to the adverse effects on crop yields of these losses .Some natural environments have both a direct and an indirect value.

Take, for example, a tropical forest. This may provide a number of direct use values, including those of timber, medicinal plants, other forest products, hunting and fishing, recreation and tourism. It may also provide indirect-use values, including soil conservation and soil productivity, and watershed protection (with consequences for water supply and storage, flood control, climate, and carbon sequestration;. The value of the forest for its indirect uses tends, however, vastly to exceed that for direct uses, giving it greater global than local value, and tending to make it more vulnerable to clearance by local people . In practice, of course, ecosystem services are essential for the maintenance of all direct-use values. Indirect-use values are more difficult to quantify or cost than direct-use values and in some cases it may be difficult to recognize, let alone explain, them. There have nonetheless been some, inevitably extremely contentious, attempts to estimate the aggregated annual value of nature’s services

Lecture 8

Maintaining of biodiversity

- **Introduction**

'Diversity of life and living systems are a necessary condition for human development'. Many question the importance of maintaining biodiversity in today's world, where conservation efforts prove costly and time-consuming. Species should be saved for 'aesthetic and moral justifications; the importance of wild species as providers of products and services are essential to human welfare. The value of particular species as indicators of environmental health or as keystone species is crucial to the functioning of ecosystems; and the scientific breakthroughs that have come from the study of wild organisms'. In other words, species serve as a source of art and entertainment. They provide products such as medicine for human well-being, indicate the welfare of the overall environment and ecosystem, and provide research that resulted in scientific discoveries.

1. Identification and monitoring

In order to know whether strategies, programmes and plans for conservation and sustainable use are appropriate and are working effectively, it will be necessary to gather suitable information.

(a) Identify components of biological diversity important for its conservation and sustainable use.

(b) Monitor, through sampling and other techniques, the components of biological diversity

(c) Identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity, and monitor their effects through sampling and other techniques.

The combination of the paucity of knowledge of biodiversity and the extraordinary magnitude of the variety of make it impossible to identify or monitor all of the components of biodiversity that lie within a nation's borders.

2. *In-situ* conservation

Biodiversity at all its levels, genetic species and as intact ecosystems, can be best preserved insitu by setting aside an adequate representation of wilderness as 'Protected Areas'. These should consist of a network of National Parks and Wildlife Sanctuaries with each distinctive ecosystem included in the network. Such a network would preserve the total diversity of life of a region.In in situ preservation include the following

(a) Establish a system of protected areas or areas where special measures need to be taken to conserve biological diversity;

(b) Develop, where necessary, guidelines for the selection, establishment and management of protected areas or areas where special measures need to be taken to conserve biological diversity; Protected area systems or networks are required to be established as a central plank of a national strategy for conserving biodiversity. More than 20,000 existing protected areas, spread amongst virtually all countries in the world, are recognized by the IUCN (The World Conservation Union) Commission on Parks and Protected Areas, covering an estimated 13.2 million km2 ; marine reserves cover about 1.3 million km2 of this total. However, this network suffers from a number of severe limitations.

1. Most protected areas are extremely small, typically of a size that is far below that required to maintain viable populations of large vertebrates

. The severity of this size constraint may be reduced if protected areas are linked by corridors, but in practice with a few notable exceptions this has not happened, and there are both pros and cons to the creation of corridors. Potential benefits include increased immigration rates, and the provision of increased or alternative refugia; potential disadvantages include facilitated transmission of fire, disease and predators, and reduction in between-populationgenetic variation (. The overall number of protected areas continues to increase, but the average size of those declared in any given period has tended to decline through time.

2. Protected areas tend to be biased towards lands of low economic value, experiencing less competition from alternative forms of land use, and towards the limits of geopolitical units (e.g. county, state and country boundaries, where they may serve as buffer zones).

3. Many areas that have been formally designated for conservation in practice receive no, little or limited protection (and have often been termed ‘paper parks’). Thus, for example, Grønne Ejland in Greenland was declared a Ramsar site (a protected area designated under the Ramsar Convention on Wetlands of International Importance) in 1987, with special reference to the presence of the world’s largest colony of Arctic terns *Sterna paradisaea* (c. 1950 estimates suggested 50,000–80,000 breeding pairs).

4 The overall extent of the existing conservation network is too small. IUCN (1993) advocates that at least 10% of the land area of each nation be set aside for conservation. The proportion of the land area set aside for conservation may be too small, but the proportion of the marine environment set aside for these purposes is much lower (c. 0.5% of ocean area). Nonetheless, existing evidence strongly supports the notion that designating protected areas of ocean has enormous benefits both for biodiversity within and without those areas, and hence for exploitation of the latter

5. The existing conservation network has been conceived along rather static lines, and is not well equipped to cope with the changes in the distributions of species that are being brought about by global climate changes These changes would normally cause shifts in the distributions of species, typically with expansions along some range boundaries and contractions along others. However, as protected areas become progressively more like islands of natural vegetation in a matrix of modified environments, often isolated from one another by considerable distances, the possibility for species to respond by such movements becomes increasingly constrained.

(c) Regulate or manage biological resources important for the conservation of biological diversity whether within or outside protected areas, with a view to assuring their conservation and sustainable use;

(d) Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings;

(e) Promote environmentally sound and sustainable development in areas adjacent to protected areas with a view to furthering protection of these areas.

(f) Restore degraded ecosystems and promote the recovery of threatened species, inter alia, through the development and implementation of plans or other management strategies.

(g) Establish or maintain means to regulate, manage or control the risks associated with the use and release of living modified organisms resulting from biotechnology which are likely to have adverse environmental impacts that could affect the conservation and sustainable use of biological diversity, taking also into account the risks to human health;

(h) Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species; The impacts on biodiversity and the environment associated with the introduction of alien species have already been mentioned , and, plainly, actions to ameliorate these effects are a necessary part of an effective conservation strategy. Prevention of invasions is much less costly than is their control once they become established, and so effective quarantine measures are vital, although presently adopted by very few nations. Eradication of established introductions is sometimes possible, particularly from islands and small areas, where action can be taken early in the invasive process, where measures can be persistently applied often over long periods (temptations to reduce efforts in response to initial success in reducing numbers must be resisted), and where there is public support for such campaigns.

(i) Endeavour to provide the conditions needed for compatibility between present uses and the conservation of biological diversity and the sustainable use of its components;

(j) Subject to its national legislation, respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement This is particularly so because there is a complex set of interactions between poverty and the environment. First, the majority of biodiversity tends to occur towards low latitudes, and there is also a decline in the wealth of nations (as measured by per capita gross national product, towards low latitudes, which means that the majority of biodiversity occurs in those nations that have the least resources with which to conduct conservation and sustainable use. Second, damage to ecosystems often impacts most directly on the poor, who suffer the effects of polluted environments, the loss of productive lands, the collapse of fisheries, and the loss of traditional sources of food, fodder, fuel and fibre when forests are cut down . The poor do not have the financial resources with which to acquire the resources that they need (food, water, etc.) from elsewhere; the large ecological footprint of the rich reduces their vulnerability to local environmental degradation. Third, as a consequence, the relative impacts of factors affecting biodiversity are not the same in poorer and richer countries .

3.Ex-situ conservation

Conservation of a species is best done by protecting its habitat along with all the other species that live in it in nature. This is known as in-situ conservation, which is conserving a species in its own environment by creating National Parks and Wildlife Sanctuaries. However, there are situations in which an endangered species is so close to extinction that unless alternate methods are instituted, the species may be rapidly driven to extinction. This strategy is known as ex-situ conservation, i.e. outside its natural habitat in a carefully controlled situation such as a botanical garden for plants or a zoological park for animals, where there is expertise to multiply the species under artificially managed conditions. These breeding programs for rare plants and animals are however more expensive than managing a Protected Area. There is also another form of preserving a plant by preserving its germ plasm in a gene bank so that it can be used if needed in future. This is even more expensive. When an animal is on the brink of extinction, it must be carefully bred so that inbreeding does not lead to the genetic makeup becoming weak.

As far as possible and as appropriate, and predominantly for the purpose of complementing in-situ measures:

(a) Adopt measures for the ex-situ conservation of components of biological diversity, preferably in the country of origin of such components;

(b) Establish and maintain facilities for ex-situ conservation of and research on plants, animals and micro-organisms, preferably in the country of origin of genetic resources;

(c) Adopt measures for the recovery and rehabilitation of threatened species and for their reintroduction into their natural habitats under appropriate conditions;

(d) Regulate and manage collection of biological resources from natural habitats for ex-situ conservation purposes so as not to threaten ecosystems and in-situ populations of species, except where special temporary ex-situ measures arerequired under subparagraph (c) above; and

(e) Cooperate in providing financial and other support for ex-situ conservation outlined in subparagraphs (a) to (d) above and in the establishment and maintenance of ex-situ conservation facilities in developing countries.

Ex-situ conservation measures may include seed banks, sperm and ova banks, culture collections (e.g. of plant tissues), artificial propagation of plants and captive breeding of animals.

- ✓ ***Preservation of Endangered Species***

It is the goal of conservationists to create and expand upon ways to preserve endangered species and maintain biodiversity. There are several ways in which one can aid in preserving the world’s species who are nearing extinction. One such way is obtaining more information on different groups of species, especially invertebrates, fungi and marine organisms, where sufficient data is lacking. For example, to understand the causes of population decline and extinction an experiment was conducted on the butterfly population in Finland. In this analysis, the butterflies' endangered list classification, distribution, density, larval specificity, dispersal ability, adult habitat breadth, flight period and body size were all recorded and examined to determine the threatened state of each species. It was found that the butterflies' distribution has declined by fifty-one and a half percent, and they have a severely restricted habitat. One example of specific butterflies who have a declining distribution rate are the Frigga's Fritillary and Grizzled Skipper, who have been affected by habitat loss due to extensive draining of the bogs where they live.

This experiment shows that when one knows the causes of endangerment, then one can successfully create solutions for the management of biodiversity. Another way to help preserve endangered species is to create a new professional society dedicated to ecological ethics. This could help ecologists make ethical decisions in their research and management of biodiversity. Also, creating more awareness on environmental ethics can help to encourage species preservation. 'Courses in ethics for students, and training programs for ecologists and biodiversity managers' all could create environmental awareness and prevent violations of ethics in research and management. One final way in which one can conserve endangered species is through federal agency investments and protection enacted by the federal government. 'Ecologists have proposed biological corridors, biosphere reserves ,ecosystem management, and ecoregional planning as approaches to integrate biodiversity conservation and socioeconomic development at increasingly larger spatial scales'. One example of a federal mandated conservation zone is the Northwest Hawaiian Islands Marine National Monument, the largest marine protected area in the world. The monument is essential for the preservation of underwater communities and overfished regions. The monument will serve as a home to an estimated 7,000 species, most of which cannot be found anywhere else in the world. This environmental monument demonstrates the fact that it is possible to create a safe environment for endangered species, as well as maintaining some of the world's largest ecosystems.

4. Sustainable use of components of biological diversity

The sustainable use of biological diversity is one of the objectives of the Conservation ,

(a) Integrate consideration of the conservation and sustainable use of biological resources into national decision-making;

(b) Adopt measures relating to the use of biological resources to avoid or minimize adverse impacts on biological diversity;

(c) Protect and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements;

(d) Support local populations to develop and implement remedial action in degraded areas where biological diversity has been reduced; and

(e) Encourage cooperation between its governmental authorities and its private sector in developing methods for sustainable uses of biological resources.

To live sustainably, the human population must do so within the biosphere's regenerative capacity, drawing on its natural capital without depleting the capital stock.